NAVAL POSTGRADUATE SCHOOL
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THESIS

EVALUATION OF FACTORS AFFECTING
REPEATABILITY AND ACCURACY
OF TURBINE RIG TEST RESULTS

by

Terry Paul Eargle

June 1980

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Evaluation of Factors Affecting Repeatability and Accuracy of Turbine Rig Test Results

by

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ABSTRACT

An experimental study was carried out to resolve anomalies and to determine the sources of inaccuracies which had hitherto been present in results from the Turbine Test Rig at the NPS Turbopropulsion Laboratory. Internal modifications to the rig's waterbrake dynamometer are reported which improved the RPM control everywhere but in the range 17,000 - 18,500 RPM. From an analysis of test results and theoretical estimates, it was concluded that with normal atmospheric humidity supply temperatures close to 700°R were necessary to eliminate the influence of water condensation on blade row performance measurements, since the stator nozzles were supersonic. A detailed uncertainty analysis was carried out which successfully isolated the major causes of inaccuracies in loss data derived from rig measurements. Recommendations were made which, if followed, should result in repeatable and accurate measurements of blade row losses.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

P	Pressure
T	Temperature
RAF	Resultant Axial Force
AXF	Axial Force (Capsule)
CLF	Closure Force (Capsule)
STM	Stator Torque (Moment)
RTM	Rotor Torque (Moment)
$\dot{W}$	Air Flow Rate
PR	Pressure Ratio

Subscripts

t	Total Condition
ref	Referred

Greek Letters

ζ	Loss Coefficient

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I. INTRODUCTION

An investigation of the performance of a turbine stage when the rotor to stator axial spacing was varied in a systematic way was carried out by Kane and reported in Reference 1. The data on maximum efficiency vs. axial spacing obtained by Kane [Fig. 21, Ref. 1], was not sufficient to determine an optimum spacing because the minimum clearance was physically limited to 0.244 in. Therefore a recommendation was made in Ref. 1 to conduct further testing by modifying the rotor to allow a closer axial spacing. The original purpose in the current investigation was to conduct the recommended tests. A second purpose was to investigate ways to make the current rig/waterbrake system more stable.

At the outset, significant revisions were required in the data acquisition programs to bring all data acquisition on-line for the first time. A first test was then conducted to checkout the rig and data acquisition system by attempting to duplicate run 7 of Ref. 1. Significant differences were noted in the interstage pressure ratios and the stator and rotor loss coefficients evaluated from the new data. In the attempt to resolve these differences, further tests were carried out which showed that the turbine stagnation temperature had a measurable effect on the pressure levels (when properly non-dimensionalised) throughout the blading, whereas stagnation pressure had no measurable effect. It was also

[illegible]

[illegible]

evident in the early tests, that the speed fluctuations were much higher than the uncertainty interval (±175 RPM) reported in Ref. 1.

The goal of the present study was to resolve the observed anomalies, and to obtain an understanding of the parameters affecting the accuracy of the data obtained from the rig. Three questions were addressed in the experimental program:

(i) What was the status of the speed control using the current waterbrake and controller, and could it be improved?

(ii) What was the cause of the observed effect of stagnation temperature?

(iii) What was the effect of the uncertainties in the measurements on the accuracy and repeatability of data derived from the rig?

The results of the investigation and responses to the above questions are contained in the main body of the report. Section II describes the test apparatus and associated instrumentation, the data reduction procedures and test program, and gives an account of the procedures followed in each test run. Section III documents the results of the investigation which are discussed in Section IV. Conclusions and recommendations are contained in Sections V and VI, respectively. A detailed calculation of the uncertainties in parameters evaluated from the rig measurements is given in Appendix C. These calculations were important in that they illustrated clearly which measured parameters govern the accuracy of data obtained from the turbine test rig.

II. TEST APPARATUS AND PROCEDURES

A. TEST EQUIPMENT

Figures 1, 2, and 3 show the test rig installation. Air to drive the turbine was provided by an Allis-Chalmers twelve stage axial compressor supplying pressure ratios of 3 to 1. Pressure ratios of 4 to 1 were obtained (6 to 1 is available) across the turbine by sealing the turbine in the hood and actuating the exhauster assembly shown in Figure 1. The exhauster assembly was an air ejector supplied from the Allis-Chalmers compressor. The exhauster reduced the pressure in the test hood to as low as half an atmosphere. Descriptions of the turbine test rig and associated instrumentation are given in Refs. 2-9.

The geometry of the stage blading is contained in Ref. 1. The different axial spacings possible with current hardware are shown in Figure 4. All tests in this investigation were run in position 1. The waterbrake reported in Ref. 1 was modified twice during the course of the present investigation. First one "slinger", and then a second, was added to attempt to attain more constant speeds. Figure 5a shows a side view of the dynamometer water wheel with two "slingers" installed. A close-up view of the water wheel with "slinger" installed is shown in Figure 5b. Prior to installation of the slingers, the water level in the dynamometer cavity would occasionally "collapse" inward, create a back

pressure, and cause a surge in RPM. The slingers were designed to prevent the water from "collapsing" inward.

B. TEST INSTRUMENTATION

A schematic of the system used to acquire the data is shown in Figure 6. The addition of the HG-78K scanivalve controller allowed the punched paper tape system used previously, to be eliminated and provided complete on-line data acquisition and storage for the first time. A total of 60 measurements were taken at each data point. Pressure measurements were taken using a 48 port Scanivalve. Fourteen other transducers were scanned for measurements of temperature, force, torque, and differential pressures. RPM was measured using an HP-5328A Universal counter. All measurements except RPM were made using an HP-3455A Digital Voltmeter. The counter and voltmeter readings were then channelled through an HP-3495A scanner to the HP-9830A computer and subsequently stored on a mass memory platter. The instruments and the computer were connected via the HP "interface bus" (HP-IB).

C. DATA ACQUISITION AND REDUCTION

Extensive modifications were required to the existing programs for data acquisition and reduction. A complete account of the modifications, descriptions of new software and current program listings are given in Appendix A.

The following changes and additions were made:

i) The data acquisition program was modified to incorporate on-line acquisition of Scanivalve and RPM data.

ii) The reduction programs developed by Solms [Ref. 7], Robbins [Ref. 8] and Boatright [Ref. 9] were modified.

iii) Software to sample, store and plot the RPM was generated.

iv) Software to determine the number of samples required to be taken of forces and torques was generated.

v) Program "UNCERT" was written to compute the uncertainties in the interstage conditions and loss coefficients evaluated from measurements.

D. TEST PROGRAM

A list of the tests conducted is shown in Table I. Three series of tests were conducted, not always in sequential order, for the following purposes:

1. To determine the number of samples required to produce a constant average in the data values from selected non-pressure channels.
2. To evaluate RPM stability at various RPM's.
3. To evaluate test rig performance at different RPM's, pressure ratios, and temperatures.

The first test series was conducted at a P.R. = 3.0 and 11500 RPM. The second and third series were conducted at a variety of RPM's and pressure ratios.

At the beginning of each test, the pressure transducer in the Scanivalve and the differential transducer for the flow nozzle were calibrated using an air source and mercury monometer. The force and torque transducers were calibrated

by applying weights and adjusting the zero and range on the signal conditioning units to give a digital output in engineering units. Using the HP9830A program "SCAMOD", given in Appendix A, data for a particular point on a given test was automatically scanned and stored. Average acquisition time took 1 minute for a turbine performance point or 65 sec. for RPM sampling. Each data point gathered on turbine performance was reduced immediately to determine if any obvious errors existed before taking the next point. At the end of the run, all turbine performance points were tabulated by batch processing.

The performance tests were conducted holding stage pressure ratio constant. This was usually done by holding P_{t_o} at a desired level and varying hood (back) pressure to obtain variations in the pressure ratio. However, in run 11, hood pressure was maintained at a constant level and P_{t_o} was raised to evaluate what effects, if any, changing stagnation pressure had on the results at constant pressure ratio. When temperature effects were being evaluated, temperature was varied by closing off all, or a portion of, the water flow to the aftercooler and allowing the new temperature to stabilize. A change in total temperature, T_{t_o}, of no more than one degree in five minutes was taken to indicate that conditions had stabilizied. Tests to evaluate the RPM stability involved taking RPM samples at a variety of RPM settings. Each "sampling" consisted of 360 points gathered over a time interval of 65 sec. The data were plotted and stored.

E. DATA STORAGE

A list of the raw data parameters recorded for the performance tests and scaling factors applied to each is contained in Appendix B. Several channels were averaged after repetitive sampling to improve accuracy, and these are also noted in Appendix B. A list of tests conducted and files and record numbers where raw and reduced data are stored is given in Table II. Table A-XV contains a list of data reduction plot routines by name, and the parameters which they plot.

F. DATA ANALYSIS

Performance test data were routinely processed using the modified reduction programs given in Appendix A.

Data from RPM sampling tests were plotted using software given in Appendix A. Also, too, RPM data sets, at different RPM's, were analyzed by Fourier analysis, using a Hewlett-Packard 9845A waveform analysis program. Each set of data was first transformed by removing the "DC" component, i.e., averaging 256 data points and then subtracting the average from each data point. The data were then fed, separately, into the program and, after transforming to the frequency domain, a power spectrum was plotted. The power spectrum used in the program employs Raleigh's Theorem of Conjugate Multiplication (see Ref. 10), to obtain the plot. After obtaining the power spectrum plots, the magnitudes of the first forty points were taken from each of the plots,

multiplied together, and used to produce a third plot. The third plot was designed to determine whether a natural frequency (and harmonics) were present at different speeds.

A comparison of calculated and measured temperature drops was made using data from runs 10-15. The procedure consisted of taking the horsepower of the stage calculated from speed and torque measurements and computing the temperature drop across the stage which would be required to produce that horsepower. The computed "delta T" was then compared to the measured "delta T" across the stage at the different stagnation pressures and temperatures of the tests.

An investigation was conducted on runs 12 and 13 to determine what effects were evident on the reduced data of inserting a constant value of $\dot{W}_{ref}$ = 1.02 lbm/sec. This was done by inserting a line 590 in program TTR2 setting $\dot{W}_{ref}$ = 1.02, re-reducing the raw data from these runs and then batch processing the results.

III. RESULTS

A. PRESENTATION OF RAW AND REDUCED DATA

The results of the Fourier Analysis applied to RPM samples taken at 15000 RPM and 19000 RPM are given in Tables III through XII. The tables contain the raw data, data transformed by removing the "DC" component, time domain presentation, frequency domain presentation, and finally, the power spectrum data for each RPM. The correlation of the first 40 points of the power spectrum for the two RPM's is presented in Tables XIII and XIV. The raw correlation is contained in Table XIII, and the referred form in Table XIV. The referred form was obtained by dividing each value in Table XIII by the largest value (point 5).

Table XV is a listing of the symbols used in Tables XVI through XXXVII. Figure 7 shows the pressure tap locations referred to in Tables XVII through XXX. The calculated and measured temperature drops from runs 10-15 are presented in Table XVI. The raw data for runs 10-15 are presented as voltages in Tables XVII through XXII. The performance data, engineering data, and converted raw data for selected parameters in runs 10-15 are presented in Tables XXIII through XXVIII. The results obtained by setting W_{ref} = 1.02 = constant are presented in Tables XXIX and XXX for runs 12 and 13. The results of tests to evaluate numbers of samples of key parameters to be averaged are presented in Table XXXI.

B. PRESENTATION OF GRAPHS

The graphs of RPM samples taken at speeds ranging from 10600 to 20000 RPM are presented in Figures 8 through 20. The sampling rate is shown on each figure. Graphs of the power spectrum for 15000 and 19000 RPM are presented in Figures 21 and 22. The correlation of these two spectrums for the first 40 points of the frequency domain is presented in Figure 23.

The graphs of four selected stage performance parameters using the data given in Tables XXIII through XXVIII are presented in Figures 24 through 27. The effects of total temperature and total pressure variations on P_1/P_{t_o}, stator nozzle taps, stator loss coefficient, and selected raw data parameters are presented in Figures 28-36. Analog records of the time variation in selected data channels are shown in Figs. 37-40.

Finally, the various aspects of repeatability are graphically depicted in Figures 41 through 46 for runs 12 and 13 (both conducted at the same T_{t_o}, P_{t_o}, and pressure ratio).

C. UNCERTAINTY ANALYSIS

An uncertainty analysis was conducted for run 10, point 1 to evaluate the uncertainty in stator and rotor loss coefficients resulting from specified uncertainties in the measurements. The detailed analysis is presented in Appendix C. An outgrowth of the analysis was the discovery of the predominant dependence of both loss coefficients on the accuracy of the calculated value of the resultant axial force. As a

result, a simplification was found which allowed the calculation of the uncertainty in the resultant axial force, P_1/P_{t_o} pressure ratio, and stator and rotor loss coefficients to be incorporated easily into a computer program, and made a part of the current reduction program sequence. Sample calculations showed only a slight deviation from exact results using this simplification (see Appendix C). The integration of this new program, called "UNCERT", into the reduction sequence is discussed in detail in Appendix A and Appendix C. It should be noted that the simplification used in the program underestimates the percentage error in stator loss coefficient by .03 times the actual error. In rotor loss coefficient the underestimate is .10 times the actual error. A complete exercise of this new program for runs 10-15 is presented in Tables XXXII to XXXVII. The uncertainties assigned to the raw data parameters presented in Appendix A were the same as those in Ref. 1. They were also consistent with the deviations found in samples conducted during the present investigation.

<u>Of note in the results of the calculations was discovery of a nearly constant uncertainty interval for each loss coefficient</u>. For the stator loss coefficient the uncertainty interval was approximately ±.03 and for rotor loss coefficient, approximately ±.05 to ±.08.

It was also discovered that the pressures on ports 11 and 21 contributed collectively, fully 65% of the uncertainty interval in the resultant axial force. These channels

correspond to hood pressure and static pressure at stator tap "HUB #3" (or clearance-plate cavity pressure) respectively. An increase in accuracy and stability in these two measurements would improve significantly the uncertainty interval in both loss coefficients. It should be noted that the analysis in Appendix C takes account only of "normal" sampling uncertainty in the measurements and does not consider errors introduced through calibration, instabilities, or repeatability problems.

Finally, anomalies occurred in the raw data on runs 13 and 15 which required altering the reduction sequence. The anomalies with modifications to the reduction program are listed in Table A-XX.

IV. DISCUSSION

A. RPM INSTABILITY

The RPM stability was examined in early tests by digitizing repetitive samples using the HP Universal counter on-line to the HP 9830A and plotting the results. This capability, which had not existed previously, quickly showed that the RPM variations were unacceptable at all RPM's. Figure 8 illustrates the problem at a low sampling rate of 27 samples per minute. RPM deviations of greater than +/- 500 RPM were common. It was also found that changing the counter control setting in the data acquisition program could drastically alter the appearance of the output. The longer was the sampling interval, the more stable appeared the RPM in the plotted output. Figures 8 through 11 illustrate this effect. The data in the four figures were taken at the same RPM and only the counter setting was changed in the acquisition program. The graphs are labelled according to sample interval. There seems to be a relationship between the sample rate and the magnitude of the recorded variations. At a sample rate of 100 samples/min., the variation was $\pm$ 200 RPM. At a sample rate of 6 samples/min., the variation was $\pm$ .2 RPM. The most useful rate seemed to be 330 samples/min., which gave relatively good repeatibility ($\pm$ 20 RPM), and gave a plot which qualitatively agreed well with independent observations of RPM variations during the tests.

Figure 8 shows results with no "slingers" installed on the waterbrake. Figures 9 through 12 were samples taken with one "slinger" installed. The RPM control was still unacceptable in that RPM variations were far in excess of those required to obtain repeatable performance data. The addition of a second "slinger" produced a marked change in stability. Figures 13 through 17 show the magnitude of the RPM excursions from the set point with two "slingers" installed. A comparison with Figures 10 and 12 illustrates the improvement obtained. The addition of the slingers clearly provided a substantial improvement in stability in the speed range up to 16500 - 17000 RPM. Between 17000 and 18500 RPM, a range of severe instability still existed, as seen in Figure 17. The RPM instability seems to decrease at 19000 to 20000 RPM as shown by Figures 18 and 19, with 20000 RPM being more stable, consistently, than 19000 RPM.

These observations suggested that there might be a natural resonance encountered between 17000 and 19000 RPM. To evaluate this possibility a Fourier analysis was carried out on two sets of data taken at RPM's of 15000 and 19000, on each side of the instability. The power spectra calculated for the two sets of data are shown in Figures 21 and 22. There were seen to be peaks in the low frequency end of the scale as was suspected from an examination of the RPM vs. time plots. The correlation of the two power spectra was calculated and is shown in Figure 23. A

definite peak at .107 Hz (period about 9.3 sec.) is evident with a second harmonic exactly at .214 Hz. It can be concluded that an unsteadiness at a frequency of .107 Hz exists which does not depend on the rotational speed. Furthermore, the low frequency of the instability suggests the problem lies within the controller or the waterbrake mechanics. Satisfactory speed stability is obtained up to and beyond the 17000 to 18500 RPM range. For the moment, it is recommended that this range be avoided when taking data. It is also recommended that further testing be undertaken to attempt to improve the speed stability in this range by small modifications of the waterbrake geometry.

B. TOTAL TEMPERATURE AND TOTAL PRESSURE EFFECTS

Runs 10 and 11 were conducted at different total pressures (59.7 and 74.5 in Hg, respectively), but at nearly equal values of the total temperature (635-639°R) and stage pressure ratio, (3.5). As can be seen in Figures 24 through 27, the various stage performance parameters, such as referred horsepower, efficiency, referred rotor torque, and referred flow rate, were measurably unaffected by total pressure changes. Also, referring to Figures 28 through 30, the stator nozzle taps and the stator exit pressure ratios are also unaffected by total pressure changes. It was concluded, therefore, that the total pressure had no measurable effect on the

interstage or stage performance parameters as long as stage pressure ratio remained constant.

Runs 10 and Runs 12 through 15 were conducted at different total temperatures (574-676°R), but at nearly equal values of the total pressure (60 inches Hg) and the same pressure ratio (3.5). Figures 24 through 27 and 31 again show that there was no perceptible difference in overall stage performance. However, the interstage performance varies markedly. Figures 28 and 29 show that there was a difference in stator nozzle tap pressure ratios at taps 3 and 4 in the supersonic portion of the nozzle. The locations of the taps are shown in Figure 7. Pressure tap 1 was not connected in these tests. Tap 2 is located at the throat of the nozzle, and taps 3 through 5 are located in the supersonic portion of the nozzle. The stator exit pressure ratios, P_{HUB}/P_{t_o}, P_1/P_{t_o}, P_{TIP}/P_{t_o}, were also examined. Figure 30 shows that there was a definite change in each of the three pressure ratios with temperature. The results for two different stage pressure ratios, 3.5 and 4.0, respectively, are shown together with data from Ref. 1 in Figures 32 and 33. Runs 8 and 9 (T_{t_o} =638°R) in the present test series differed from Runs 10 and 11 in Ref. 1 (T_{t_o} =670°R), in total temperature only. The same temperature effect was evident at both pressure ratios. Finally, Figures 34 through 36 show the effect of temperature on the referred stator torque, resultant axial force, and stator loss coefficient, respectively. Again, the effect was clearly measurable.

In attempting to explain the variations in interstage parameters with total temperature, it should be noted that changes in stagnation pressure and temperature should produce no changes in any <u>referred</u> quantities (such as referred stator torque) at given values of pressure ratio and referred speed, unless geometry changes occur or the Reynolds number is particularly low. Also, at a constant total pressure, total temperature should have no effect on pressure ratios in the flow of a perfect gas through a De Laval nozzle. The observed pressure ratio differences in particular in the values of P_1/P_{t_o}, evident in Figures 29, 31, and 32, in turn affect the calculation of other interstage parameters such as the resultant axial force (RAF) and the stator loss coefficient. In fact the differences evident in these derived parameters with total temperature are directly related to the shifts in P_1/P_{t_o} with total temperature. Several avenues were investigated to explain the temperature effect. A summary follows:

(1) <u>Effect of Reynolds Number</u>

Differences in the nozzle boundary layer development resulting from the effect of stagnation temperature on the Reynolds number were considered. However, the Reynolds number variation obtained by changing stagnation pressure level more than overlapped the variation obtained by changing stagnation temperature. Since the results were unaffected by stagnation pressure changes, this could not be the mechanism.

(2) Non-Perfect Gas Effects

The effect of temperature on the gas constant, ratio of specific heats and compressibility factor for air in the range of temperature of the tests, was found to have an insignificant effect on the predicted nozzle ratios.

(3) Thermal Expansion Effects

Geometry changes as a result of thermal effects could occur and affect the measurements in a variety of ways. It is important to note first that uniform expansion of the stator nozzles, so that A/A* remained constant, would leave the stator pressure ratio's unaffected.

The observed decrease in static pressure ratio (or increase in Mach number) at increased stagnation temperature, would imply that the throat area was required to expand proportionately less than than the downstream section of the nozzle. Calculations were carried out assuming no change in the throat size and linear growth of the aluminum nozzle material to the higher temperature. The change in area ratio was calculated to be less than 0.003. At tap 4 in the stator nozzles, the pressure ratio increased from 0.281 in Run 11 to 0.310 in Run 12. This corresponded to an area ratio decrease from 1.162 to 1.120 (using isentropic gas tables), or an area ratio change of 0.042. This was an order of magnitude greater than could be explained by simple thermal expansion.

The fractional change in the throat area of the stator nozzles due to thermal expansion between the lowest and highest stagnation temperatures, would also be less than 0.003. An examination of the values of the referred flow rate, which is a measure of the throat area if the flow is choked, revealed that for all tests except Run 12 they ranged within ±0.005 of the value 1.025. This was consistent with the uncertainty calculated in Appendix C, resulting from the basic uncertainty in the individual measurements. In order to examine the effect of the small variations in $\dot{W}_{ref}$ on the calculated parameters, the data of Run 12 and Run 13 were re-reduced using $\dot{W}_{ref} = 1.02$ in place of the measured flow rate (see Tables XXIX and XXX). A negligible effect on the values of interstage pressure ratio was observed.

The effect of temperature on the labyrinth leak rate was questioned. In the existing reduction programs the effect of temperature on the "kinetic energy" factor had been included in the original calibration of Robbins [Ref. 8]. No correction was included however for the effect of temperature on the labyrinth clearance. When this was added (Appendix A), the effect on the results was found to be negligible.

It was concluded that thermal expansion could not explain the observed effect of temperature on nozzle pressure ratios.

(4) Condensation

It was questioned whether condensation could be occurring in flow in the supersonic portion of the nozzle. Condensation would certainly alter the static pressure levels, and condensation of the same air had been observed in the flow from a Mach 1.4 nozzle exhausting into the laboratory. A calculation was done to determine static temperatures in the flow assuming an isentropic expansion of air and water vapor through the stator nozzle. The calculation is presented in detail in Appendix D. The calculation predicted supercooled conditions for the water vapor in the entire supersonic portion of the nozzle. Supercooling in excess of 100° F was predicted at a stagnation temperature (T_{t_o}) of 574° R. A higher T_{t_o} (670° R) resulted in supercooling of only 37° F at the nozzle exit plane. Refs. 14 and 15 state that supersonic flow containing water vapor, supercooled by 90-110° F will result in condensation. The data for low T_{t_o} fall precisely in this range, so that condensation might well have occurred. Inspection of columns P2 through P4 in Tables XXIII to XXVIII reveals that as total temperature was raised, the values in these columns progressed non-linearly toward the values for the highest total temperature, (Run 15 - T_{t_o} = 676° R).

A test was conducted at a total temperature of 575° R and pressure ratio of 3.5 with the rotor removed, and hood exhausted to see if condensation could be observed

(visually) in the flow exiting the stator nozzle. No condensation was observed, but it should be noted that following the calculation in Appendix D, only 4.6% of the small amount of water in the flow must condense to effect observed changes in the stator nozzle pressure ratio at M = 1.2. The small scale of the nozzles, the swirling flow geometry and the background of metallic surfaces, did not help the detection process.

A comparison of the temperature drops through the stage calculated from the torque-measurement of power, with the value measured using thermocouple probes is shown in Table XVI. It can be seen that the difference between the two measures is large at the low supply temperature, and small for the high temperature runs. Since the measurements of the referred power were in good agreement for all tests, the difference must be the result of an error in the outlet thermocouple indication, or in the assumption of perfect gas made in the calculation. Both effects would accompany the occurrence of condensation. It was therefore concluded that the changes experienced in nozzle pressure ratios and stator exit pressure ratios were directly related to condensation effects in the nozzle. It is noted however that operation at the highest temperature gave consistent results, so that condensation effects were absent, or minor.

While testing at high total temperatures in Run 15 (T_{t_o} = 676° R), several pressure ports "blew" due to

the plastic pressure tubing currently used; the plastic tubing softened, and failed at the elevated temperature. In order to obtain consistent, reliable results from the rig measurements, it is essential that high total temperatures be used to suppress condensation. It is therefore recommended that 1) the rig be reinstrumented using high temperature plastic tubing. (Plastic tubing is currently available commercially for use at temperatures up to 250° F (710° R).) It is also recommended that 2) a minimum run total temperature no lower than 680° R, and preferably higher, be adopted for all performance testing in which interstage measurements are needed. To ensure that the highest total temperature is attained consistently, it is recommended that the aftercooler be drained when conducting such tests.

C. CALCULATION OF THE REFERRED FLOW RATE AND LOSS COEFFICIENTS

Sequential scanning of the fourteen nonpressure channels revealed that for a given RPM, temperature and pressure variations were extremely small for normal RPM variations (±175 RPM). For this reason, the temperatures and all pressures except one were eliminated from the scan averaging techniques employed in Ref. 1 (see also Appendix A). It was found that channel 24, the stator exit tip static pressure, was observed visually on the mercury manometer board to oscillate ± 0.50 in Hg during tests. Channel 24 was therefore averaged when taking data (see Appendix A for full details). In addition, the

two force and two torque measurements were examined to determine how many samples per run point were required to produce a repeatable average value of the measurement. Table XXXI shows the results of this experiment. It can be seen that approximately 30 averaged samples produced a repeatable average in these parameters. On the basis of these results a 30 scan sequence was included in the acquisition program. It is also of note that the variations in stator torque and resultant axial force after 30 scans are consistent with the uncertainty intervals assigned in Ref. 1 and in this report.

Time traces of the analog output of axial force, closure force, stator torque, and rotor torque in comparison with an analog recording of the RPM are presented in Figures 37 to 40. The traces were taken at 16000 RPM. The variations in both force measurements were seen to correlate well with RPM variations and this implies that improvements in RPM stability will also result in reduced uncertainty in the computation of resultant axial force. It should be remembered however, that, as shown in Appendix D, the two pressure port measurements (11 and 21) overwhelmingly dominate in producing the uncertainty in the resultant axial force. The variation of stator torque with RPM was small and this was consistent with the 100 sample survey in Table XXXI. Finally, the variations in the rotor torque were larger than in the stator torque which again was consistent with the results of Table XXXI. However, the rotor torque variations were seen to correlate poorly with RPM variations and exhibited the most noise and scatter.

Three key parameters, $\dot{W}_{ref}$, ζ_S, and ζ_R, are calculated in the course of the data reduction, and the accuracy obtained depends on many measurements. What follows is a discussion of the various factors affecting the calculation of these three parameters:

A comparison of Runs 12 and 13 revealed that there were differences in both $\dot{W}_{ref}$ and ζ_S which could not be readily explained by the differences in total temperature, total pressure, or by the possible occurrence of condensation. Both runs were conducted at identical temperatures (574° R), pressures (60 in Hg), pressure ratios (3.5), and relative humidities (70%). Inspection of Tables XXV and XXVI revealed approximately a 1/2 % change in $\dot{W}_{ref}$. In addition, Figure 41 showed clearly that there were differences in ζ_S. Calculations of $\dot{W}_{ref}$ involve three measurements; the pressure and the temperature upstream of and the pressure difference across the flow nozzle, which is located in the line from the Allis-Chalmers compressor to the rig inlet plenum. By interrogating the reduction programs it was revealed that the effects of small (realistic) changes in nozzle pressure or temperature affected the values of $\dot{W}_{ref}$ very slightly. However, the value of $\dot{W}_{ref}$ was affected significantly by small (but realistic) changes in the pressure drop across the flow nozzle. Point 3 on Run 12 and point 5 on Run 13 were compared. It was found that the ΔP across the nozzle was 20.884 in H_2O for the first point and 21.079 for the second point. This is a change of .195 in H_2O representing a .9% change in

value; but this difference is sufficient to explain most of the difference in the $\dot{W}_{ref}$. Inspection of all values of $\dot{W}_{ref}$ for Runs 10-15 revealed only ± .002 lbm/sec variation in the magnitude in any given run. However, the average $\dot{W}_{ref}$ changed slightly from run to run. Based on the comparison of Runs 12 and 13, this would appear to be due to slight drifts in transducer output during different tests, or to minor calibration errors either before or during the runs. It is therefore recommended that the calibration of the ΔP nozzle transducer be checked rigorously by the investigator at intervals throughout each test.

A re-reduction of data from Runs 12 and 13 was carried out with $\dot{W}_{ref}$ = 1.02 lbm/sec = constant entered into the program as discussed in Section IV.B. This re-reduced data is presented in Tables XXIX and XXX. The original stator loss coefficient data are shown in Figure 41 and the re-reduced data are shown in Figure 42. It can be seen that, while the calculated stator loss coefficients were in better agreement than before, they were still higher in Run 13. The effects of $\dot{W}_{ref}$ then do not account totally for the differences seen in ζ_S (and ζ_R). The data in Figure 43 illustrates that, although there were differences in ζ_S and ζ_R that again, stage performance parameters were nearly the same. Figures 44, 45 and 46, containing data from Run 12 and Run 13 show that there was only a slight difference in measured stator torque between the two runs, <u>but a definite correlation exists in the behavior of the calculated resultant axial force</u> (<u>RAF</u>)

and the calculated interstage pressure ratio (P_1/P_{t_o}). The distribution of the data in Figures 45 and 46 is entirely similar. This result is in complete agreement with the results of the uncertainty analysis given in Appendix D which emphasizes the dominance of RAF on the calculation of P_1/P_{t_o}. This also points to the necessity for an extremely careful calibration of the force capsules before each run.

The stator hub and tip pressures, on ports 21 and 24, were observed (on the mercury manometer board) to exhibit unsteady behavior. The unsteadiness on Port 24 was qualitatively worse than on port 21 by about a factor of two. The acquisition program was altered initially to average both these ports over 30 scans. However, this resulted in the Scanivalve having to cycle completely through 48 channels for each of the 30 samples. This procedure required 300 cycles of the Scanivalve to obtain ten data points in each performance test. Excessive scanivalve wear would result from such a procedure. It was therefore decided to only average port 24 since it was observed to be the most unsteady. However, the uncertainty analysis revealed that port 21 exercises a far greater influence on the uncertainty in the resultant axial force than does port 24, by a factor of nearly 26. In selecting between the two measurements, port 21 should have been averaged, not port 24. It is therefore recommended that a pneumatic damper be inserted in the pressure lines to each of ports 21 and 24. An improvement in the steadiness of the pressure at these two ports, particularly 21, should result

in a significant improvement in the steadiness and reliability of the calculated values of resultant axial force, interstage pressure ratio, stator and rotor loss coefficients. The proper averaging of the pressures on these two ports would do more to improve the reliability and smoothness of the output calculations than any other recommendation which has been made. Hood pressure, the other key input affecting the resultant axial force calculation, was observed to be very steady throughout all tests.

In summary, it is recommended that, prior to each run, the investigator, with the cooperation of the test engineer, carry out a systematic verification of the calibration of the measurements shown to have a controlling effect on the reduced data. Where practical, calibrations should be verified at intervals throughout the test period. The key parameters and recommended procedures to follow are given in Appendix E.

V. CONCLUSIONS

1. The speed control of the waterbrake and turbine system manifests a characteristic frequency of .107 Hz at speeds of both 15,000 and 19,000 RPM.

2. There is a region of instability in the RPM control between 17000 - 18500 RPM which is caused by either instability in the flow of water through the waterbrake or by the inability of the controller to control the turbine output characteristic in this range.

3. Operation of the rig is satisfactory outside the range of the instability.

4. Variations in P_{t_o}, with stage pressure ratio held constant, have no measurable influence on the interstage or stage performance parameters.

5. Variations in T_{t_o}, with stage pressure ratio held constant had no measurable effect on stage performance. Changes experienced in stator nozzle pressure ratio and stator exit pressure ratios (and consequently, loss coefficients) were directly related to condensation effects beginning in the stator nozzle.

6. Approximately 30 scans of stator and rotor torque and axial and closure force measurements were required to produce a repeatable average for a given data point.

7. The pressure drop across the flow nozzle, ΔP_{noz}, has the greatest influence of the three input measurements on the calculated value of W_{ref}.

8. To ensure accurate computation of RAF, a careful, accurate calibration of the force measurements must be conducted before each run.

9. Pressure ports 11 (hood pressure) and 21 (stator exit hub pressure) exert a disproportionate influence on the uncertainty in calculating the resultant axial force (RAF), stator exit pressure, and stator and rotor loss coefficients. An increase in accuracy in measuring these two pressures would result in a significant decrease in the variations found in each of the above-mentioned calculated parameters.

10. The stator exit hub pressure on Port 21, is unsteady and exerts a stronger influence on the uncertainty in RAF than does the tip pressure on port 24.

11. A pneumatic damper on ports 21 and 24 would do more to improve the accuracy of the calculated values of the resultant axial force, interstage pressure, stator and rotor loss coefficients than any other change which could be made.

12. A nearly constant uncertainty interval exists in ζ_S of $\pm.0300$ and in ζ_R of $\pm.05$ to $.08$.

VI. RECOMMENDATIONS

1. The speed range of 17000 - 18500 RPM be avoided until the waterbrake instability in this area is corrected.

2. Further tests be conducted to attempt to improve the waterbrake stability by perturbing the internal geometry.

3. The pressure tubing inside the hood be replaced with high temperature plastic tubing to allow the use of temperatures up to 710 °R.

4. A minimum total temperature of 680° R or higher be adopted to avoid condensation effects when interstage data is taken. This can be done by draining the aftercooler.

5. A pneumatic damper be incorporated in the port 21 and port 24 pressure lines to improve accuracy in calculating interstage parameters. An improvement in speed stability will alleviate, but not eliminate this requirement.

6. The investigator should check the calibration of the ΔP_{noz} transducer before and after each data point to ensure accuracy in $\dot{W}_{ref}$.

7. The investigator should cooperate with the test engineer to verify the calibration of key measurements by following, at a minimum, the steps listed in Appendix E.

8. Merging the acquisition and reduction programs should be considered and implemented if found to be practicable.

TABLE I

TESTS CONDUCTED

TURBINE PERFORMANCE TESTS

Run Number	T_{t_o} (°R)	P_{t_o} ("Hg)	Pressure Ratio	RPM
8	639	59.8	3.5	10040-18870
9	643	59.6	4.0	11000-18750
10	635	59.7	3.5	11077-19346
11	639	74.5	3.5	11129-18017
12	574	59.8	3.5	12214-19046
13	574	59.9	3.5	12085-20009
14	602	60.0	3.5	12075-19987
15	676	59.9	3.6	12081-19940

RPM SAMPLE TESTS

Run Number	Pressure Ratio	RPM
1	3.0	10600
2	3.0	11600
3	3.0	11600
4	3.0	11600
5	3.0	11600
6	3.0	13000
7	3.0	14100
8	3.0	15100

9	3.0	16100
10	3.5	17400
11	3.0	19000
12	3.5	20000

*RPM samples were taken on most occasions between performance test points. No attempt has been made to equate these run numbers with those listed as turbine performance tests. RPM sample tests are sequentially numbered and correspond to the order of graphs of results presented in the report.

DATA SAMPLE TEST

One test was run to determine the number of samples needed to produce a constant average in the forces (two measurements), and torques (two measurements). The test was run at 11500 RPM, pressure ratio of 3.0, and 100 samples were taken of each parameter of interest.

TABLE II

STORAGE LOCATION OF RAW AND REDUCED DATA

TURBINE PERFORMANCE TESTS

Run Number	Record Number	File Name
1	1-10	
2	11-20	
3	erased	
4	21-30	Raw Data in file
5	31-40	"RAWDAT"
6	41-50	
7	51-59	Reduced Data in
8	erased	file "REDDAT"
9	erased	
10	60-68	
11	69-76	
12	77-82	
13	83-90	
14	91-98	
15	99-106	

RPM SAMPLE TESTS

# Slingers	RPM	Record Number	File Name
1	11500	1-3	
1	11500	4-6	
1	11500	7-9	
1	11500	10-12	Data stored in
1	11500	13-15	file "RPMSTO"
2	11500	16-18	
2	11500	19-21	
2	10400	22-24	
2	13100	25-27	
2	19000	28-30	
2	13100	31-33	
2	14100	34-36	
2	15100	37-39	
2	19000	40-42	
2	17100	43-45 erased	
2	19000	43-45	
2	20000	46-48	
2	19000	49-51	

UNCERTAINTY MEASUREMENTS

Run Number	Record Number	File Name
10	1-9	
11	10-17	
12	18-23	Stored in "DATAZ",
13	24-31	for performance
14	32-39	test data.
15	40-47	

TABLE III. RPM SAMPLES AT 15,000 RPM

#	X	Y	#		Y
1	14980	0	2	[illegible]	0
3	15100	0	4	15080	0
5	15060	0	6	15040	0
7	15040	0	8	15060	0
9	15080	0	10	15060	0
11	15040	0	12	15040	0
13	15020	0	14	15080	0
15	15100	0	16	15080	0
17	15080	0	18	15100	0
19	15120	0	20	15120	0
21	15200	0	22	15180	0
23	15120	0	24	15100	0
25	15100	0	26	15140	0
27	15140	0	28	15120	0
29	15100	0	30	15140	0
31	15160	0	32	15240	0
33	15240	0	34	15240	0
35	15260	0	36	15240	0
37	15200	0	38	15160	0
39	15140	0	40	15140	0
41	15140	0	42	15080	0
43	15040	0	44	15020	0
45	14960	0	46	14960	0
47	15000	0	48	15040	0
49	15100	0	50	15140	0
51	15100	0	52	15120	0
53	15100	0	54	15080	0
55	15060	0	56	15060	0
57	15080	0	58	15100	0
59	15100	0	60	15080	0
61	15080	0	62	15080	0
63	15040	0	64	15060	0
65	15100	0	66	15100	0
67	15120	0	68	15200	0
69	15160	0	70	15180	0
71	15180	0	72	15140	0
73	15120	0	74	15120	0
75	15120	0	76	15140	0
77	15140	0	78	15160	0
79	15180	0	80	15160	0
81	15160	0	82	15100	0
83	15100	0	84	15120	0
85	15120	0	86	15080	0
	15060	0	88	15060	
	15060	0	90	15060	

TABLE III (Cont'd)

[illegible]	[illegible]0	0	92	15[illegible]	[illegible]
93	[illegible]0	0	94	15060	0
95	15040	0	96	15040	0
97	15040	0	98	15040	0
99	15080	0	100	15120	0
101	15100	0	102	15120	0
103	15060	0	104	15080	0
105	15100	0	106	15100	0
[illegible]	5120	0	108	[illegible]	[illegible]
[illegible]	5140	0	110	[illegible]	[illegible]
[illegible]	5100	0	112	[illegible]	[illegible]
113	15120	0	114	15140	0
115	15120	0	116	15100	0
117	15080	0	118	15080	0
119	15060	0	120	15060	0
121	15060	0	122	15080	0
123	15100	0	124	15100	0
125	15060	0	126	15100	0
127	15120	0	128	15120	0
129	15140	0	130	15100	0
131	15140	0	132	15120	0
133	15160	0	134	15140	0
135	15160	0	136	15140	0
137	15120	0	138	15140	0
139	15120	0	140	15100	0
141	15100	0	142	15120	0
143	15120	0	144	15100	0
145	15140	0	146	15180	0
147	15140	0	148	15140	0
149	15140	0	150	15140	0
151	15120	0	152	15080	0
153	15080	0	154	15060	0
155	15080	0	156	15100	0
157	15120	0	158	15120	0
159	15160	0	160	15200	0
161	15220	0	162	15260	0
163	15220	0	164	15180	0
165	15140	0	166	15160	0
167	15120	0	168	15120	0
169	15180	0	170	15180	0
171	15200	0	172	15180	0
173	15100	0	174	15060	0
175	15060	0	176	15080	0
[illegible]	15120	0	178	15100	[illegible]
[illegible]	15080	0	180	150[illegible]	[illegible]

TABLE III (Cont'd)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
185	[illegible]	0	[illegible]	15180	0
187	[illegible]	0	188	15140	0
189	15140	0	190	15140	0
191	15180	0	192	15160	0
193	15140	0	194	15140	0
195	15100	0	196	15080	0
197	15080	0	198	15040	0
199	15080	0	200	15100	0
201	15140	0	202	15120	0
203	15080	0	204	15080	0
205	15100	0	206	15120	0
207	15100	0	208	15120	0
209	15140	0	210	15120	0
211	15100	0	212	15100	0
213	15140	0	214	15120	0
215	15120	0	216	15060	0
217	15040	0	218	15080	0
219	15100	0	220	15080	0
221	15100	0	222	15060	0
223	15040	0	224	15040	0
225	15040	0	226	15020	0
227	15040	0	228	15040	0
229	15040	0	230	15060	0
231	15140	0	232	15200	0
[illegible]	15200	0	234	15180	[illegible]
[illegible]	5220	0	236	15200	[illegible]
[illegible]	5180	0	238	15180	[illegible]
[illegible]	15160	0	240	15160	0
241	15160	0	242	15160	0
243	15160	0	244	15120	0
245	15120	0	246	15100	0
247	15080	0	248	15080	0
249	15100	0	250	15060	0
251	15080	0	252	15080	0
253	15060	0	254	15040	0
255	15060	0	256	15120	0

TABLE IV

RPM UNSTEADY COMPONENT AT 15000 RPM

AVG = 15110.46875

-130.46875	-90.46875	-10.46875	-30.46875
-50.46875	-70.46875	-70.46875	-50.46875
-30.46875	-50.46875	-70.46875	-70.46875
-90.46875	-30.46875	-10.46875	-30.46875
-30.46875	-10.46875	9.53125	9.53125
89.53125	69.53125	9.53125	-10.46875
-10.46875	29.53125	29.53125	9.53125
-10.46875	29.53125	49.53125	129.53125
129.53125	129.53125	149.53125	129.53125
89.53125	49.53125	29.53125	29.53125
29.53125	-30.46875	-70.46875	-90.46875
-150.46875	-150.46875	-110.46875	-70.46875
-10.46875	29.53125	-10.46875	9.53125
-10.46875	-30.46875	-50.46875	-50.46875
-30.46875	-10.46875	-10.46875	-30.46875
-30.46875	-30.46875	-70.46875	-50.46875
-10.46875	-10.46875	9.53125	89.53125
49.53125	69.53125	69.53125	29.53125
9.53125	9.53125	9.53125	29.53125
29.53125	49.53125	69.53125	49.53125
49.53125	-10.46875	-10.46875	9.53125
9.53125	-30.46875	-50.46875	-50.46875
-50.46875	-50.46875	-50.46875	-10.46875
-10.46875	-50.46875	-70.46875	-70.46875
-70.46875	-70.46875	-30.46875	9.53125
-10.46875	9.53125	-50.46875	-30.46875
-10.46875	-10.46875	9.53125	9.53125
29.53125	-10.46875	-10.46875	9.53125
9.53125	29.53125	9.53125	-10.46875
-30.46875	-30.46875	-50.46875	-50.46875
-50.46875	-30.46875	-10.46875	-10.46875
-50.46875	-10.46875	9.53125	9.53125
29.53125	-10.46875	29.53125	9.53125
49.53125	29.53125	49.53125	29.53125
9.53125	29.53125	9.53125	-10.46875
-10.46875	9.53125	9.53125	-10.46875
29.53125	69.53125	29.53125	29.53125
29.53125	29.53125	9.53125	-30.46875
-30.46875	-50.46875	-30.46875	-10.46875
9.53125	9.53125	49.53125	89.53125
109.53125	149.53125	109.53125	69.53125
29.53125	49.53125	9.53125	9.53125

TABLE IV (Cont'd)

69.53125	69.53125	89.53125	69.53125
-10.46875	-50.46875	-50.46875	-30.46875
9.53125	-10.46875	-30.46875	-30.46875
-30.46875	29.53125	49.53125	29.53125
49.53125	69.53125	29.53125	29.53125
29.53125	29.53125	69.53125	49.53125
29.53125	29.53125	-10.46875	-30.46875
-30.46875	-70.46875	-30.46875	-10.46875
29.53125	9.53125	-30.46875	-30.46875
-10.46875	9.53125	-10.46875	9.53125
29.53125	9.53125	-10.46875	-10.46875
29.53125	9.53125	9.53125	-50.46875
-70.46875	-30.46875	-10.46875	-30.46875
-10.46875	-50.46875	-70.46875	-70.46875
-70.46875	-90.46875	-70.46875	-70.46875
-70.46875	-50.46875	29.53125	69.53125
89.53125	69.53125	109.53125	89.53125
69.53125	69.53125	49.53125	49.53125
49.53125	49.53125	49.53125	9.53125
9.53125	-10.46875	-30.46875	-30.46875
-10.46875	-50.46875	-30.46875	-30.46875
-50.46875	-70.46875	-50.46875	9.53125

TABLE V

TIME DOMAIN DATA

NUMBER OF DATA POINTS = 256
TIME=0 TO 4.65455E+01[SEC]
TIME INTERVAL= 1.81818E-01[SEC]

DATA POINT	TIME[SEC]	DATA
1	0.00000E+00	-1.30469E+02
2	1.81818E-01	-9.04688E+01
3	3.63636E-01	-1.04688E+01
4	5.45455E-01	-3.04688E+01
5	7.27273E-01	-5.04688E+01
6	9.09091E-01	-7.04688E+01
7	1.09091E+00	-7.04688E+01
8	1.27273E+00	-5.04688E+01
9	1.45455E+00	-3.04688E+01
10	1.63636E+00	-5.04688E+01
11	1.81818E+00	-7.04688E+01
12	2.00000E+00	-7.04688E+01
13	2.18182E+00	-9.04688E+01
14	2.36364E+00	-3.04688E+01
15	2.54545E+00	-1.04688E+01
16	2.72727E+00	-3.04688E+01
17	2.90909E+00	-3.04688E+01
18	3.09091E+00	-1.04688E+01
19	3.27273E+00	9.53125E+00
20	3.45455E+00	9.53125E+00
21	3.63636E+00	8.95313E+01
22	3.81818E+00	6.95313E+01
23	4.00000E+00	9.53125E+00
24	4.18182E+00	-1.04688E+01
25	4.36364E+00	-1.04688E+01
26	4.54545E+00	2.95313E+01
27	4.72727E+00	2.95313E+01
28	4.90909E+00	9.53125E+00
29	5.09091E+00	-1.04688E+01
30	5.27273E+00	2.95313E+01
31	5.45455E+00	4.95313E+01
32	5.63636E+00	1.29531E+02
33	5.81818E+00	1.29531E+02
34	6.00000E+00	1.29531E+02
35	6.18182E+00	1.49531E+02
36	6.36364E+00	1.29531E+02
37	6.54545E+00	8.95313E+01
38	6.72727E+00	4.95313E+01
39	6.90909E+00	2.95313E+01
40	7.09091E+00	2.95313E+01

TABLE V (Cont'd)

41	7.27273E+00	2.95313E+01
42	[illegible]	-3.04688E+01
43	7.63636E+00	-7.04688E+01
44	7.81818E+00	-9.04688E+01
45	8.00000E+00	-1.50469E+02
46	8.18182E+00	-1.50469E+02
47	8.36364E+00	-1.10469E+02
48	8.54545E+00	-7.04688E+01
49	8.72727E+00	-1.04688E+01
50	[illegible]	2.95313E+01
[illegible]	[illegible]	-1.04688E+01
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
54	[illegible]	-3.04688E+01
55	9.81818E+00	-5.04688E+01
56	1.00000E+01	-5.04688E+01
57	1.01818E+01	-3.04688E+01
58	1.03636E+01	-1.04688E+01
59	1.05455E+01	-1.04688E+01
60	1.07273E+01	-3.04688E+01
61	1.09091E+01	-3.04688E+01
62	1.10909E+01	-3.04688E+01
63	1.12727E+01	-7.04688E+01
64	1.14545E+01	-5.04688E+01
65	1.16364E+01	-1.04688E+01
66	1.18182E+01	-1.04688E+01
67	1.20000E+01	9.53125E+00
68	1.21818E+01	8.95313E+01
69	1.23636E+01	4.95313E+01
70	1.25455E+01	6.95313E+01
71	1.27273E+01	6.95313E+01
72	1.29091E+01	2.95313E+01
73	1.30909E+01	9.53125E+00
74	1.32727E+01	9.53125E+00
75	1.34545E+01	9.53125E+00
76	1.36364E+01	2.95313E+01
77	1.38182E+01	2.95313E+01
78	1.40000E+01	4.95313E+01
79	1.41818E+01	6.95313E+01
80	1.43636E+01	4.95313E+01

TABLE V (Cont'd)

	[illegible]	4.95[illegible]
82	[illegible]	-1.04688E+01
83	1.49091E+01	-1.04688E+01
84	1.50909E+01	9.53125E+00
85	1.52727E+01	9.53125E+00
86	1.54545E+01	-3.04688E+01
87	1.56364E+01	-5.04688E+01
88	1.58182E+01	-5.04688E+01
89	1.60000E+01	-5.04688E+01
90	1.61818E+01	-5.04688E+01
91	1.63636E+01	-5.04688E+01
92	1.65455E+01	-1.04688E+01
93	1.67273E+01	-1.04688E+01
94	1.69091E+01	-5.04688E+01
95	1.70909E+01	-7.04688E+01
96	1.72727E+01	-7.04688E+01
97	1.74545E+01	-7.04688E+01
98	1.76364E+01	-7.04688E+01
99	1.78182E+01	-3.04688E+01
100	1.80000E+01	9.53125E+00
101	1.81818E+01	-1.04688E+01
102	1.83636E+01	9.53125E+00
103	1.85455E+01	-5.04688E+01
104	1.87273E+01	-3.04688E+01
105	1.89091E+01	-1.04688E+01
106	1.90909E+01	-1.04688E+01
107	1.92727E+01	9.53125E+00
108	1.94545E+01	9.53125E+00
109	1.96364E+01	2.95313E+01
110	1.98182E+01	-1.04688E+01
111	2.00000E+01	-1.04688E+01
112	2.01818E+01	9.53125E+00
113	2.03636E+01	9.53125E+00
114	2.05455E+01	2.95313E+01
115	2.07273E+01	9.53125E+00
116	2.09091E+01	-1.04688E+01
117	2.10909E+01	-3.04688E+01
118	2.12727E+01	-3.04688E+01
119	2.14545E+01	-5.04688E+01
120	2.16364E+01	-5.04688E+01

TABLE V (Cont'd)

121	2.18182E+01	-5.04688E+01
122	2.20000E+01	-3.04688E+01
123	2.21818E+01	-1.04688E+01
124	2.23636E+01	-1.04638E+01
125	2.25455E+01	-5.04688E+01
126	2.27273E+01	-1.04688E+01
127	2.29091E+01	9.53125E+00
128	2.30909E+01	9.53125E+00
129	2.32727E+01	2.95313E+01
130	2.34545E+01	-1.04688E+01
131	2.36364E+01	2.95313E+01
132	2.38182E+01	9.53125E+00
133	2.40000E+01	4.95313E+01
134	2.41818E+01	2.95313E+01
135	2.43636E+01	4.95313E+01
136	2.45455E+01	2.95313E+01
137	2.47273E+01	9.53125E+00
138	2.49091E+01	2.95313E+01
139	2.50909E+01	9.53125E+00
140	2.52727E+01	-1.04688E+01
141	2.54545E+01	-1.04688E+01
142	2.56364E+01	9.53125E+00
143	2.58182E+01	9.53125E+00
144	2.60000E+01	-1.04688E+01
145	2.61818E+01	2.95313E+01
146	2.63636E+01	6.95313E+01
147	2.65455E+01	2.95313E+01
148	2.67273E+01	2.95313E+01
149	2.69091E+01	2.95313E+01
150	2.70909E+01	2.95313E+01
151	2.72727E+01	9.53125E+00
152	2.74545E+01	-3.04688E+01
153	2.76364E+01	-3.04688E+01
154	2.78182E+01	-5.04688E+01
155	2.80000E+01	-3.04688E+01
156	2.81818E+01	-1.04688E+01
157	2.83636E+01	9.53125E+00
158	2.85455E+01	9.53125E+00
159	2.87273E+01	4.95313E+01
160	2.89091E+01	8.95313E+01

TABLE V (Cont'd)

[illegible]	2.90909E+01	1.09531E+02
162	2.92727E+01	1.49531E+02
163	2.94545E+01	1.09531E+02
164	2.96364E+01	6.95313E+01
165	2.98182E+01	2.95313E+01
166	3.00000E+01	4.95313E+01
167	3.01818E+01	9.53125E+00
168	3.03636E+01	9.53125E+00
[illegible]	3.05455E+01	6.95313E+01
[illegible]	3.07273E+01	6.95313E+01
171	3.09091E+01	8.95313E+01
172	3.10909E+01	6.95313E+01
173	3.12727E+01	-1.04688E+01
174	3.14545E+01	-5.04688E+01
175	3.16364E+01	-5.04688E+01
176	3.18182E+01	-3.04688E+01
177	3.20000E+01	9.53125E+00
178	3.21818E+01	-1.04688E+01
179	3.23636E+01	-3.04688E+01
180	3.25455E+01	-3.04688E+01
181	3.27273E+01	-3.04688E+01
182	3.29091E+01	2.95313E+01
183	3.30909E+01	4.95313E+01
184	3.32727E+01	2.95313E+01
185	3.34545E+01	4.95313E+01
186	3.36364E+01	6.95313E+01
187	3.38182E+01	2.95313E+01
188	3.40000E+01	2.95313E+01
189	3.41818E+01	2.95313E+01
190	3.43636E+01	2.95313E+01
191	3.45455E+01	6.95313E+01
192	3.47273E+01	4.95313E+01
193	3.49091E+01	2.95313E+01
194	3.50909E+01	2.95313E+01
195	3.52727E+01	-1.04688E+01
196	3.54545E+01	-3.04688E+01
197	3.56364E+01	-3.04688E+01
198	3.58182E+01	-7.04688E+01
199	3.60000E+01	-3.04688E+01
200	3.61818E+01	-1.04688E+01

TABLE V (Cont'd)

201	3.63636E+01	2.95313E+01
202	3,65455E+01	9,53125E+00
203	3.67273E+01	-3,04688E+01
204	3.69091E+01	-3.04688E+01
205	3,70909E+01	-1,04688E+01
206	3,72727E+01	9,53125E+00
207	3.74545E+01	-1,04688E+01
208	3.76364E+01	9,53125E+00
209	3.78182E+01	2,95313E+01
210	3.80000E+01	9,53125E+00
211	3,81818E+01	-1,04688E+01
212	3.83636E+01	-1.04688E+01
213	3,85455E+01	2,95313E+01
214	3,87273E+01	9,53125E+00
215	3,89091E+01	9,53125E+00
216	3,90909E+01	-5,04688E+01
217	3,92727E+01	-7,04688E+01
218	3,94545E+01	-3,04688E+01
219	3,96364E+01	-1.04688E+01
220	3,98182E+01	-3.04688E+01
221	4.00000E+01	-1,04688E+01
222	4,01818E+01	-5,04688E+01
223	4.03636E+01	-7,04688E+01
224	4,05455E+01	-7,04688E+01
225	4,07273E+01	-7,04688E+01
226	4,09091E+01	-9,04688E+01
227	4,10909E+01	-7.04688E+01
228	4,12727E+01	-7.04689E+01
229	4.14545E+01	-7.04688E+01
230	4.16364E+01	-5.04688E+01
231	4,18182E+01	2.95313E+01
232	4,20000E+01	8,95313E+01
233	4.21818E+01	8,95313E+01
234	4.23636E+01	6,95313E+01
235	4.25455E+01	1.09531E+02
236	4,27273E+01	8.95313E+01
237	4,29091E+01	6.95313E+01
238	4.30909E+01	6.95313E+01
239	4.32727E+01	4.95313E+01
240	4.34545E+01	4.95313E+01

TABLE V (Cont'd)

[illegible]	4.36364E+01	4.95313E+01
242	4.38182E+01	4.95313E+01
243	4.40000E+01	4.95313E+01
244	4.41818E+01	9.53125E+00
245	4.43636E+01	9.53125E+00
246	4.45455E+01	-1.04688E+01
247	4.47273E+01	-3.04688E+01
248	4.49091E+01	-3.04688E+01
249	4.50909E+01	-1.04688E+01
250	4.52727E+01	-5.04688E+01
251	4.54545E+01	-3.04688E+01
252	4.56364E+01	-3.04688E+01
253	4.58182E+01	-5.04688E+01
254	4.60000E+01	-7.04688E+01
255	4.61818E+01	-5.04688E+01
[illegible]	4.63636E+01	9.53125E+00

TABLE VI

FREQUENCY DOMAIN DATA

REQUENCY WINDOW=0 TO 2.75000E+00[Hz]
REQUENCY INTERVAL= 2.14844E-02[Hz]

COEFF.	FREQUENCY[Hz]	REAL	IMAG	MAGNITUDE	PHASE[DEG]
C TERM	0.00000E+00	0.00000E+00			
X FREQ.	2.75000E+00	0.00000E+00			
1	2.14844E-02	-7.02140E+00	8.31356E+00	1.08819E+01	130.18
2	4.29688E-02	-4.53011E+00	-1.49749E+01	1.56451E+01	-106.83
3	6.44531E-02	8.78196E-01	5.80495E+00	5.87100E+00	81.40
4	8.59375E-02	-9.52862E+00	5.35053E-01	9.54363E+00	176.79
5	1.07422E-01	-2.28104E+01	8.23003E+00	2.42497E+01	160.16
6	1.28906E-01	-1.63501E+01	2.52672E+01	3.00958E+01	122.91
7	1.50391E-01	-1.65496E+00	1.09040E+01	1.10289E+01	98.63
8	1.71875E-01	3.46512E-01	-1.04759E+01	1.04816E+01	-88.11
9	1.93359E-01	-5.83263E+00	1.88343E+00	6.12918E+00	162.10
10	2.14844E-01	-6.56539E-01	-2.47107E+01	2.47194E+01	-91.52
11	2.36328E-01	6.56960E+00	-9.28349E+00	1.13729E+01	-54.71
12	2.57813E-01	-2.60729E-01	8.83748E+00	8.84132E+00	91.69
13	2.79297E-01	-3.14266E+00	8.46112E+00	9.02590E+00	110.38
14	3.00781E-01	1.54004E+01	7.51768E+00	1.71373E+01	26.02
15	3.22266E-01	6.85749E+00	2.43352E+00	7.27648E+00	19.54
16	3.43750E-01	5.24993E+00	-9.23535E+00	1.06232E+01	-60.38
17	3.65234E-01	-1.25718E+01	-4.87202E+00	1.34828E+01	-158.82
18	3.86719E-01	-9.12445E+00	-5.73891E+00	1.07792E+01	-147.83
19	4.08203E-01	-7.38371E-01	3.94879E+00	4.01723E+00	100.59
20	4.29688E-01	-3.87050E+00	-2.95985E+00	4.87252E+00	-142.59
21	4.51172E-01	5.43498E+00	-1.81511E+00	5.73006E+00	-18.47
22	4.72656E-01	4.24586E-01	8.19398E+00	8.20497E+00	87.03
23	4.94141E-01	3.52328E+00	-5.78434E+00	6.77289E+00	-58.65
24	5.15625E-01	-4.05755E-01	6.19418E+00	6.20745E+00	93.75
25	5.37109E-01	-3.94952E+00	9.56106E+00	1.03447E+01	112.44
26	5.58594E-01	1.31184E+00	-4.68747E+00	4.86757E+00	-74.37
27	5.80078E-01	9.93151E-01	-6.96054E+00	7.03104E+00	-81.88
28	6.01563E-01	-6.59283E+00	-2.18423E+00	6.94524E+00	-161.67
29	6.23047E-01	-3.50754E+00	8.64102E-01	3.61241E+00	166.16
30	6.44531E-01	9.14433E-01	5.95268E+00	6.02251E+00	81.27
31	6.66016E-01	2.98276E+00	-3.61861E+00	4.68948E+00	-50.50
32	6.87500E-01	3.02562E+00	-6.10811E+00	6.81640E+00	-63.65
33	7.08984E-01	1.44179E-01	4.98976E+00	4.99184E+00	88.34
34	7.30469E-01	-4.57387E+00	-4.50546E+00	6.42024E+00	-135.43
35	7.51953E-01	-1.92420E+00	-5.23073E-01	1.99403E+00	-164.79
36	7.73438E-01	6.19173E+00	7.60210E+00	9.80457E+00	50.84
37	7.94922E-01	-2.14562E+00	1.04779E-01	2.14818E+00	177.20
38	8.16406E-01	1.09925E+00	6.99721E-01	1.30306E+[illegible]	[illegible]
[illegible]	[illegible].37891E-01	1.06419E+00	-2.09872E+00	2.35311E+[illegible]	[illegible]

TABLE VI (Cont'd)

40	[illegible]E-01	-1.47818E+00	-4.49089E+00	4.7279[illegible]	[illegible]
41	8.80859E-01	2.14066E+00	-4.13356E+00	4.65497E+00	-62.62
42	9.02344E-01	1.51962E+00	1.54043E+00	2.16383E+00	45.39
43	9.23828E-01	-3.21545E+00	1.06439E+00	3.38704E+00	161.68
44	9.45313E-01	-4.85195E+00	-1.61634E-01	4.85464E+00	-178.09
45	9.66797E-01	-4.21918E+00	-6.05999E-01	4.26248E+00	-171.83
46	9.88281E-01	-3.25301E+00	1.91562E+00	3.77514E+00	149.51
47	1.00977E+00	-4.82362E+00	-1.09172E-01	4.82485E+00	-178.70
48	1.03125E+00	1.82595E+00	3.24752E+00	3.72565E+00	60.65
49	1.05273E+00	-4.31825E-01	2.69930E+00	2.73362E+00	99.09
50	1.07422E+00	1.53275E-01	-5.34120E-01	5.55677E-01	-73.[illegible]
51	[illegible]E+00	1.84387E+00	1.61757E+00	2.45283E+00	41.[illegible]
52	[illegible]E+00	-9.32933E-01	2.59941E+00	2.76176E+00	[illegible]
53	1.13867E+00	-1.29609E+00	-3.23155E+00	3.48178E+00	-111.8[illegible]
54	1.16016E+00	3.76591E-01	1.91414E+00	1.95084E+00	78.87
55	1.18164E+00	-1.16508E+00	1.96309E+00	2.28279E+00	120.69
56	1.20313E+00	-4.00404E+00	4.02544E+00	5.67772E+00	134.85
57	1.22461E+00	-3.59129E+00	8.86039E-01	3.69897E+00	166.14
58	1.24609E+00	6.18702E-01	2.26769E+00	2.35058E+00	74.74
59	1.26758E+00	3.18393E+00	-9.85305E-01	3.33290E+00	-17.20
60	1.28906E+00	1.77718E-01	3.89440E-01	4.28074E-01	65.47
61	1.31055E+00	2.04796E-01	2.39098E+00	2.39974E+00	85.10
62	1.33203E+00	-3.71906E-01	5.43294E-03	3.71945E-01	179.16
63	1.35352E+00	-2.42373E+00	2.65463E+00	3.59466E+00	132.40
64	1.37500E+00	4.68750E-01	4.68750E-01	6.62913E-01	45.00
65	1.39648E+00	7.93919E-01	8.31793E-01	1.14986E+00	46.33
66	1.41797E+00	-4.41786E+00	1.67257E+00	4.72387E+00	159.26
67	1.43945E+00	-9.41065E-01	1.10211E+00	1.44922E+00	130.49
68	1.46094E+00	-2.80306E+00	-1.69564E-01	2.80818E+00	-176.54
69	1.48242E+00	3.64787E-01	7.54600E-01	8.38148E-01	64.20
70	1.50391E+00	-1.38463E+00	2.47770E+00	2.83834E+00	119.20
71	1.52539E+00	-2.74257E-01	2.23734E+00	2.25409E+00	96.99
72	1.54688E+00	1.75796E-01	3.43704E+00	3.44153E+00	87.07
73	1.56836E+00	1.66749E+00	1.38267E+00	2.16618E+00	39.67
74	1.58984E+00	-1.05343E+00	2.05064E+00	2.30540E+00	117.19
75	1.61133E+00	-2.87200E+00	1.53089E+00	3.25453E+00	151.94
76	1.63281E+00	6.41357E-01	1.68072E+00	1.79893E+00	69.11
77	1.65430E+00	-3.50697E+00	-5.49277E-01	3.54973E+00	-171.10
78	1.67573E+00	-1.36506E+00	-2.36373E+00	2.72958E+00	[illegible]
79	1.6[illegible]E+00	-5.70852E-01	6.55152E-01	8.68963E-01	[illegible]

TABLE VI (Cont'd)

[illegible]	[illegible]E+00	-1.09371E+00	2.20551E-01	1.1157[illegible]	[illegible]
81	1.[illegible]E+00	-7.75717E-01	-5.49652E-01	9.50712E-01	-144.68
82	1.76172E+00	-3.24035E+00	9.46357E-01	3.37572E+00	163.72
83	1,78320E+00	-2.37853E+00	2.97173E+00	3.80639E+00	128.67
84	1,80469E+00	-4.19054E-02	-1.16424E+00	1.16500E+00	-92.06
85	1,82617E+00	-1.53113E+00	-1.10971E-01	1.53515E+00	-175.85
86	1.84766E+00	-1,06824E+00	-1.35872E-01	1.07685E+00	-172.75
87	1,86914E+00	-1.85782E+00	3.59185E+00	4.04387E+00	117.35
88	1.89063E+00	-8.93383E-01	3.05749E+00	3.18533E+00	106.29
89	1.91211E+00	6.91265E-01	-9.10357E-01	1.14306E+00	-52.79
90	1.93359E+00	1.13818E+00	1.23205E-01	1.14483E+00	6.18
91	1.95508E+00	-1.81576E+00	5.90650E-01	1.90941E+00	161.98
92	1.97656E+00	6.02578E-01	-1.98829E+00	2.07760E+00	-73.14
93	1.99805E+00	4.35826E-01	-3.30314E-01	5.46856E-01	-37.16
94	2.01953E+00	-4.83768E-01	3.33587E+00	3.37077E+00	98.25
95	2.04102E+00	-1.64803E+00	2.62684E+00	3.10102E+00	122.10
96	2.06250E+00	1.03688E+00	1.41893E-01	1.04654E+00	7.79
97	2,08398E+00	-7.11063E-01	6.32471E-01	9.51646E-01	138.35
98	2.10547E+00	-1.90244E+00	2.00929E+00	2.76705E+00	133.44
99	2.12695E+00	1.08589E+00	1.12136E+00	1.56096E+00	45.92
100	2.14844E+00	-9.53113E-01	2.79339E-01	9.93205E-01	163.67
101	2.16992E+00	-4.82686E-01	-5.71686E-01	7.48205E-01	-130.18
102	2.19141E+00	-4.59728E-01	6.07324E-01	7.61703E-01	127.12
103	2,21289E+00	-2.15382E+00	-3.47223E-02	2.15410E+00	-179.08
104	2.23438E+00	-5.30743E-01	-8.32787E-02	5.37237E-01	-171.08
105	2.25586E+00	-9.58001E-01	-1.17961E+00	1.51962E+00	-129.08
106	2.27734E+00	8.45109E-01	2.72916E+00	2.85701E+00	72.79
107	2.29883E+00	-1.57500E+00	-1.35633E+00	2.07852E+00	-139.27
[illegible]	2.32031E+00	-1.70998E+00	2.19022E+00	2.77869E+[illegible]	[illegible].99
[illegible]	[illegible]E+00	-1.43933E+00	-1.62636E-01	1.44849E+[illegible]	[illegible]
[illegible]	[illegible]E+00	-6.05533E-01	5.70253E-01	8.31781E-[illegible]	[illegible]
111	[illegible]E+00	-7.81351E-01	2.23783E+00	2.37032E+00	[illegible]
112	2.40625E+00	-9.82158E-01	8.62688E-01	1.30724E+00	138.71
113	2.42773E+00	-1.55108E+00	1.02505E+00	1.85919E+00	146.54
114	2.44922E+00	2.99750E-01	1.65628E+00	1.68318E+00	79.74
115	2.47070E+00	2,30480E-01	-1.73347E+00	1.74873E+00	-82.43
116	2.49219E+00	1.54440E+00	4.47102E-01	1.60781E+00	16.15
117	2.51367E+00	-3.02466E+00	-1.10791E+00	3.22118E+00	-159.88
118	2.53516E+00	-1.90784E-01	3.37547E-01	3.87732E-01	119.48
119	2.55664E+00	-9.15621E-01	-1.26374E+00	1.56058E+00	-125.92
120	2.57813E+00	-7.10209E-01	1.09913E-01	7.18664E-01	171.20
121	2.59961E+00	-7.43019E-01	4.73766E-01	8.81210E-01	147.48
122	2.62109E+00	5.97358E-01	1.74426E-01	6.22303E-01	16.28
123	2.64258E+00	-1,20809E+00	-6.64337E-01	1,37870E+00	-151.19
124	2.66406E+00	-1.12178E-01	9.05643E-01	9,12564E-01	97.06
125	2.68555E+00	-9,86286E-01	-5.38748E-01	1,12384E+00	-151.35
[illegible]	[illegible]E+00	3.32753E-01	-1.27702E+00	1,31966[illegible]	
[illegible]	[illegible]E+00	7.67470E-02	-1.82571E+00	1.82732[illegible]	

TABLE VII

POWER

COEFF.	FREQ.[Hz]	POWER	( )/MAX
DC	0.00000E+00	0.00000E+00	0.000
MAX	2.75000E+00	0.00000E+00	0.000
1	2.14844E-02	1.18415E+02	.131
2	4.29688E-02	2.44768E+02	.270
3	6.44531E-02	3.44687E+01	.038
4	8.59375E-02	9.10808E+01	.101
5	1.07422E-01	5.88049E+02	.649
6	1.28906E-01	9.05759E+02	1.000
7	1.50391E-01	1.21636E+02	.134
8	1.71875E-01	1.09864E+02	.121
9	1.93359E-01	3.75669E+01	.041
10	2.14844E-01	6.11050E+02	.675
11	2.36328E-01	1.29343E+02	.143
12	2.57813E-01	7.81690E+01	.086
13	2.79297E-01	8.14669E+01	.090
14	3.00781E-01	2.93687E+02	.324
15	3.22266E-01	5.29472E+01	.058
16	3.43750E-01	1.12853E+02	.125
17	3.65234E-01	1.81786E+02	.201
18	3.86719E-01	1.16191E+02	.128
19	4.08203E-01	1.61381E+01	.018
20	4.29688E-01	2.37415E+01	.026
21	4.51172E-01	3.28336E+01	.036
22	4.72656E-01	6.73215E+01	.074
23	4.94141E-01	4.58721E+01	.051
24	5.15625E-01	3.85324E+01	.043
25	5.37109E-01	1.07013E+02	.118
26	5.58594E-01	2.36933E+01	.026
27	5.80078E-01	4.94355E+01	.055
28	6.01563E-01	4.82363E+01	.053
29	6.23047E-01	1.30495E+01	.014
30	6.44531E-01	3.62706E+01	.040
31	6.66016E-01	2.19912E+01	.024
32	6.87500E-01	4.64633E+01	.051
33	7.08984E-01	2.49135E+01	.028
34	7.30469E-01	4.12194E+01	.046
35	7.51953E-01	3.97614E+00	.004
36	7.73438E-01	9.61296E+01	.106
37	7.[illegible]4922E-01	4.61467E+00	.005
[illegible]	8.[illegible]406E-01	1.69797E+00	.002
[illegible]	[illegible]891E-01	5.53715E+00	.006

TABLE VII (Cont'd)

[illegible]	[illegible]5E-01	2.23531E+01	.025
41	8.80859E-01	2.16687E+01	.024
42	9.02344E-01	4.68218E+00	.005
43	9.23828E-01	1.14720E+01	.013
44	9.45313E-01	2.35675E+01	.026
45	9.66797E-01	1.81687E+01	.020
46	9.88281E-01	1.42517E+01	.016
47	1.00977E+00	2.32792E+01	.026
48	1.03125E+00	1.38805E+01	.015
49	1.05273E+00	7.47269E+00	.008
50	1.07422E+00	3.08777E-01	.000
51	1.09570E+00	6.01639E+00	.007
52	1.11719E+00	7.62732E+00	.008
53	1.13867E+00	1.21228E+01	.013
54	1.16016E+00	3.80576E+00	.004
55	1.18164E+00	5.21114E+00	.006
56	1.20313E+00	3.22365E+01	.036
57	1.22461E+00	1.36824E+01	.015
58	1.24609E+00	5.52522E+00	.006
59	1.26758E+00	1.11082E+01	.012
60	1.28906E+00	1.83247E-01	.000
61	1.31055E+00	5.75875E+00	.006
62	1.33203E+00	1.38343E-01	.000
63	1.35352E+00	1.29216E+01	.014
64	1.37500E+00	4.39453E-01	.000
65	1.39648E+00	1.32219E+00	.001
66	1.41797E+00	2.23150E+01	.025
67	1.43945E+00	2.10024E+00	.002
68	1.46094E+00	7.88588E+00	.009
69	1.48242E+00	7.02491E-01	.001
70	1.50391E+00	8.05617E+00	.009
71	1.52539E+00	5.08092E+00	.006
72	1.54688E+00	1.18441E+01	.013
73	1.56836E+00	4.69232E+00	.005
74	1.58984E+00	5.31485E+00	.006
75	1.61133E+00	1.05920E+01	.012
76	1.63281E+00	3.23616E+00	.004
77	1.65430E+00	1.26005E+01	.014
78	1.67578E+00	7.45059E+00	.008
79	1.69727E+00	7.55097E-01	.001
80	1.71875E+00	1.24485E+00	.001
81	1.74023E+00	9.03854E-01	.001
82	1.76172E+00	1.13955E+01	.013
83	1.78320E+00	1.44886E+01	.016
84	1.80469E+00	1.35722E+00	.001
85	1.82617E+00	2.35668E+00	.003
86	1.[illegible]766E+00	1.15960E+00	.001
87	1.[illegible]914E+00	1.63529E+01	.018

TABLE VII (Cont'd)

[illegible]	[illegible]3E+00	1.01464E+0[illegible]	[illegible]
89	1.91211E+00	1.30660E+00	.001
90	1.93359E+00	1.31063E+00	.001
91	1.95508E+00	3.64585E+00	.004
92	1.97656E+00	4.31641E+00	.005
93	1.99805E+00	2.99051E-01	.000
94	2.01953E+00	1.13621E+01	.013
95	2.04102E+00	9.61632E+00	.011
96	2.06250E+00	1.09526E+00	.001
97	2.08398E+00	9.05631E-01	.001
98	2.10547E+00	7.65656E+00	.008
99	2.12695E+00	2.43661E+00	.003
100	2.14844E+00	9.86455E-01	.001
101	2.16992E+00	5.59811E-01	.001
102	2.19141E+00	5.80192E-01	.001
103	2.21289E+00	4.64016E+00	.005
104	2.23438E+00	2.88624E-01	.000
105	2.25586E+00	2.30924E+00	.003
106	2.27734E+00	8.16251E+00	.009
107	2.29883E+00	4.32025E+00	.005
108	2.32031E+00	7.72112E+00	.009
109	2.34180E+00	2.09812E+00	.002
110	2.36328E+00	6.91860E-01	.001
111	2.38477E+00	5.61841E+00	.006
112	[illegible].40[illegible]5E+00	1.70886E+[illegible]	.00[illegible]
11[illegible]	[illegible]3E+00	3.45658E+[illegible]	.004
114	[illegible].44[illegible]2E+00	2.83311E+00	.003
115	2.47070E+00	3.05805E+00	.003
116	2.49219E+00	2.58507E+00	.003
117	2.51367E+00	1.03760E+01	.011
118	2.53516E+00	1.50336E-01	.000
119	2.55664E+00	2.43540E+00	.003
120	2.57813E+00	5.16478E-01	.001
121	2.59961E+00	7.76531E-01	.001
122	2.62109E+00	3.87261E-01	.000
123	2.64258E+00	1.90081E+00	.002
124	2.66406E+00	8.32774E-01	.001
125	2.68555E+00	1.26301E+00	.001
12[illegible]	[illegible]E+00	1.74151E+00	.002
12[illegible]	[illegible]52E+00	3.33910E+00	.004

TABLE VIII

#	X	Y	#	X	Y
1	19000	0	2	19060	0
3	19180	0	4	19100	0
5	18940	0	6	18900	0
7	18840	0	8	18780	0
9	18720	0	10	18560	0
11	18440	0	12	18840	0
13	19140	0	14	19220	0
15	19340	0	16	19360	0
17	19200	0	18	18960	0
19	18980	0	20	19160	0
21	19100	0	22	19180	0
23	19180	0	24	19100	0
25	19020	0	26	19020	0
27	18860	0	28	18880	0
29	19180	0	30	19280	0
31	19340	0	32	19280	0
33	19220	0	34	19100	0
35	18940	0	36	19000	0
37	19180	0	38	19120	0
39	19000	0	40	19060	0
41	19060	0	42	18880	0
43	18680	0	44	18700	0
45	18680	0	46	18780	0
47	19040	0	48	19260	0
49	19200	0	50	19020	0
51	18740	0	52	18440	0
53	18320	0	54	18400	0
55	18600	0	56	18720	0
57	18900	0	58	19020	0
59	18860	0	60	18620	0
61	18840	0	62	19160	0
63	19260	0	64	19260	0
65	19240	0	66	19400	0
67	19280	0	68	19040	0
69	19040	0	70	19280	0
71	19400	0	72	19360	0
73	19180	0	74	18940	0
75	19000	0	76	18940	0
77	19160	0	78	18960	0
79	18980	0	80	18980	0
81	18740	0	82	18840	0
83	19020	0	84	19300	0
[illegible]	19260	0	86	19240	0
[illegible]	[illegible]400	0	88	1936[illegible]	[illegible]
[illegible]	[illegible]080	0	90	191[illegible]	[illegible]

TABLE VIII (Cont'd)

	19240	0	92	[illegible]	
93	19160	0	94	18960	
95	19080	0	96	19020	0
97	18980	0	98	19200	0
99	19320	0	100	19280	0
101	19080	0	102	18940	0
103	18760	0	104	18660	0
105	18600	0	106	18600	0
	18520	0	108	18660	
	18760	0	110	18580	
	18540	0	112	18600	
113	18540	0	114	18460	0
115	18560	0	116	18760	0
117	18980	0	118	18980	0
119	18840	0	120	18740	0
121	18720	0	122	18760	0
123	18700	0	124	19040	0
125	19040	0	126	19180	0
127	19280	0	128	19140	0
129	19100	0	130	19060	0
131	19300	0	132	19040	0
133	18760	0	134	18900	0
135	19020	0	136	19220	0
137	19220	0	138	19200	0
139	19100	0	140	19320	0
141	19400	0	142	19440	0
143	19460	0	144	19380	0
145	19280	0	146	19160	0
147	19080	0	148	19140	0
149	18940	0	150	18780	0
151	18820	0	152	18880	0
153	18940	0	154	19140	0
155	19260	0	156	19320	0
157	19280	0	158	19140	0
159	19020	0	160	18880	0
161	18540	0	162	18520	0
163	18880	0	164	19220	0
165	19160	0	166	19140	0
167	19240	0	168	19200	0
169	19360	0	170	19340	0
171	19340	0	172	19180	0
173	19140	0	174	19280	0
175	19160	0	176	18800	0
[illegible]	3720	0	178	1899[illegible]	[illegible]
[illegible]	3940	0	180	1902[illegible]	[illegible]

TABLE VIII (Cont'd)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
185	[illegible]	[illegible]	186	19180	0
187	18900	0	188	19000	0
189	19280	0	190	19300	0
191	19280	0	192	19200	0
193	19080	0	194	18780	0
195	18700	0	196	18780	0
197	18960	0	198	19060	0
199	19220	0	200	19280	0
201	19220	0	202	19160	0
203	19120	0	204	18820	0
205	18920	0	206	18820	0
207	19100	0	208	19180	0
209	19340	0	210	19160	0
211	19080	0	212	18960	0
213	18700	0	214	18680	0
215	18920	0	216	19020	0
217	18960	0	218	18940	0
219	19040	0	220	19160	0
221	19060	0	222	18940	0
223	19020	0	224	19100	0
225	19180	0	226	19180	0
227	19120	0	228	19140	0
229	19240	0	230	19140	0
231	19100	0	232	19180	0
[illegible]	[illegible]	0	234	[illegible]	[illegible]
[illegible]	[illegible]	0	236	[illegible]	[illegible]
[illegible]	[illegible]	0	238	[illegible]	[illegible]
[illegible]	[illegible]	0	240	[illegible]	[illegible]
241	19120	0	242	19000	0
243	19140	0	244	19100	0
245	19020	0	246	18940	0
247	18820	0	248	18560	0
249	18360	0	250	18440	0
251	18740	0	252	19140	0
[illegible]	[illegible]	0	254	19100	[illegible]
[illegible]	[illegible]	0	256	18940	[illegible]

TABLE IX

RPM UNSTEADY COMPONENT AT 19000 RPM

AVG = 19016.484375

-16.484375	163.515625	-76.484375	-176.484375
-296.484375	-576.484375	123.515625	323.515625
183.515625	-36.484375	83.515625	163.515625
3.515625	-156.484375	163.515625	323.515625
203.515625	-76.484375	163.515625	-16.484375
43.515625	-336.484375	-336.484375	23.515625
183.515625	-276.484375	-696.484375	-416.484375
-116.484375	-156.484375	-176.484375	243.515625
223.515625	263.515625	23.515625	383.515625
163.515625	-16.484375	143.515625	-36.484375
-276.484375	3.515625	243.515625	383.515625
63.515625	223.515625	143.515625	63.515625
-36.484375	303.515625	63.515625	-256.484375
-416.484375	-496.484375	-256.484375	-476.484375
-476.484375	-456.484375	-36.484375	-176.484375
-296.484375	-316.484375	23.515625	263.515625
83.515625	283.515625	-256.484375	3.515625
203.515625	83.515625	383.515625	443.515625
263.515625	63.515625	-76.484375	-196.484375
-76.484375	243.515625	263.515625	3.515625
-476.484375	-136.484375	143.515625	223.515625
343.515625	323.515625	123.515625	143.515625
-296.484375	-76.484375	-136.484375	-176.484375
363.515625	-116.484375	263.515625	263.515625
63.515625	-316.484375	-56.484375	203.515625
203.515625	103.515625	-96.484375	83.515625
323.515625	63.515625	-316.484375	-96.484375
-56.484375	23.515625	43.515625	3.515625
163.515625	103.515625	223.515625	83.515625
203.515625	103.515625	-216.484375	83.515625
103.515625	123.515625	3.515625	-196.484375
-656.484375	-276.484375	223.515625	63.515625
43.515625	83.515625	-116.484375	-236.484375
-456.484375	-176.484375	203.515625	343.515625
-56.484375	143.515625	163.515625	83.515625
3.515625	-136.484375	263.515625	263.515625
83.515625	-16.484375	103.515625	43.515625
-136.484375	-316.484375	-236.484375	243.515625

TABLE IX (Cont'd)

3.515625	-576.484375	-616.484375	-296.484375
3.515625	-396.484375	143.515625	243.515625
383.515625	23.515625	263.515625	343.515625
-76.484375	-76.484375	-56.484375	-36.484375
-176.484375	283.515625	223.515625	343.515625
83.515625	223.515625	-56.484375	3.515625
183.515625	263.515625	-76.484375	-356.484375
-416.484375	-356.484375	-436.484375	-416.484375
-556.484375	-256.484375	-36.484375	-276.484375
-256.484375	23.515625	163.515625	123.515625
43.515625	23.515625	-116.484375	203.515625
183.515625	303.515625	423.515625	363.515625
143.515625	123.515625	-236.484375	-136.484375
123.515625	303.515625	123.515625	-136.484375
-496.484375	203.515625	123.515625	183.515625
323.515625	163.515625	263.515625	-216.484375
-36.484375	3.515625	-156.484375	63.515625
163.515625	-16.484375	283.515625	183.515625
-236.484375	-236.484375	43.515625	263.515625
143.515625	-196.484375	-196.484375	163.515625
143.515625	-56.484375	-336.484375	3.515625
-76.484375	143.515625	-76.484375	83.515625
163.515625	123.515625	123.515625	163.515625
163.515625	103.515625	-216.484375	23.515625
-16.484375	83.515625	-76.484375	-456.484375
-576.484375	123.515625	83.515625	-76.484375

TABLE X

TIME DOMAIN DATA

NUMBER OF DATA POINTS = 256
TIME=0 TO 4.65455E+01[SEC]
TIME INTERVAL= 1.81818E-01[SEC]

DATA POINT	TIME[SEC]	DATA
1	0.00000E+00	-1.64844E+01
2	1.81818E-01	4.35156E+01
3	3.63636E-01	1.63516E+02
4	5.45455E-01	8.35156E+01
5	7.27273E-01	-7.64844E+01
6	9.09091E-01	-1.16484E+02
7	1.09091E+00	-1.76484E+02
8	1.27273E+00	-2.36484E+02
9	1.45455E+00	-2.96484E+02
10	1.63636E+00	-4.56484E+02
11	1.81818E+00	-5.76484E+02
12	2.00000E+00	-1.76484E+02
13	2.18182E+00	1.23516E+02
14	2.36364E+00	2.03516E+02
15	2.54545E+00	3.23516E+02
16	2.72727E+00	3.43516E+02
17	2.90909E+00	1.83516E+02
18	3.09091E+00	-5.64844E+01
19	3.27273E+00	-3.64844E+01
20	3.45455E+00	1.43516E+02
21	3.63636E+00	8.35156E+01
22	3.81818E+00	1.63516E+02
23	4.00000E+00	1.63516E+02
24	4.18182E+00	8.35156E+01
25	4.36364E+00	3.51563E+00
26	4.54545E+00	3.51563E+00
27	4.72727E+00	-1.56484E+02
28	4.90909E+00	-1.36484E+02
29	5.09091E+00	1.63516E+02
30	5.27273E+00	2.63516E+02
31	5.45455E+00	3.23516E+02
32	5.63636E+00	2.63516E+02
33	5.81818E+00	2.03516E+02
34	6.00000E+00	8.35156E+01
35	6.18182E+00	-7.64844E+01
36	6.36364E+00	-1.64844E+01
37	6.54545E+00	1.63516E+02
38	6.72727E+00	1.03516E+02
39	6.90909E+00	-1.64844E+01
40	7.09091E+00	4.35156E+01

TABLE X (Cont'd)

41	[illegible]	[illegible]
42	7.45455E+00	-1.36484E+02
43	7.63636E+00	-3.36484E+02
44	7.81818E+00	-3.16484E+02
45	8.00000E+00	-3.36484E+02
46	8.18182E+00	-2.36484E+02
47	8.36364E+00	2.35156E+01
48	8.54545E+00	2.43516E+02
49	8.72727E+00	1.83516E+02
50	8.90909E+00	3.51563E+00
51	9.09091E+00	-2.76484E+02
52	9.27273E+00	-5.76484E+02
53	9.45455E+00	-6.96484E+02
54	9.63636E+00	-6.16484E+02
55	9.81818E+00	-4.16484E+02
56	1.00000E+01	-2.96484E+02
57	1.01818E+01	-1.16484E+02
58	1.03636E+01	3.51563E+00
59	1.05455E+01	-1.56484E+02
60	1.07273E+01	-3.96484E+02
61	1.09091E+01	-1.76484E+02
62	1.10909E+01	1.43516E+02
63	1.12727E+01	2.43516E+02
64	1.14545E+01	2.43516E+02
65	1.16364E+01	2.23516E+02
66	1.18182E+01	3.83516E+02
67	1.20000E+01	2.63516E+02
68	1.21818E+01	2.35156E+01
69	1.23636E+01	2.35156E+01
70	1.25455E+01	2.63516E+02
71	1.27273E+01	3.83516E+02
72	1.29091E+01	3.43516E+02
73	1.30909E+01	1.63516E+02
74	1.32727E+01	-7.64844E+01
75	1.34545E+01	-1.64844E+01
76	1.36364E+01	-7.64844E+01
77	1.38182E+01	1.43516E+02
78	1.40000E+01	-5.64844E+01
79	1.41818E+01	-3.64844E+01
80	1.43636E+01	-3.64844E+01

TABLE X (Cont'd)

81	[illegible]E+01	-2.76484E+02
82	1.[illegible]E+01	-1.76484E+02
83	1.49091E+01	3.51563E+00
84	1.50909E+01	2.83516E+02
85	1.52727E+01	2.43516E+02
86	1.54545E+01	2.23516E+02
87	1.56364E+01	3.83516E+02
88	1.58182E+01	3.43516E+02
89	1.60000E+01	6.35156E+01
90	1.61818E+01	8.35156E+01
91	1.63636E+01	2.23516E+02
92	1.65455E+01	2.23516E+02
93	1.67273E+01	1.43516E+02
94	1.69091E+01	-5.64844E+01
95	1.70909E+01	6.35156E+01
96	1.72727E+01	3.51563E+00
97	1.74545E+01	-3.64844E+01
98	1.76364E+01	1.83516E+02
99	1.78182E+01	3.03516E+02
100	1.80000E+01	2.63516E+02
101	1.81818E+01	6.35156E+01
102	1.83636E+01	-7.64844E+01
103	1.85455E+01	-2.56484E+02
104	1.87273E+01	-3.56484E+02
105	1.89091E+01	-4.16484E+02
106	1.90909E+01	-4.16484E+02
107	1.92727E+01	-4.96484E+02
108	1.94545E+01	-3.56484E+02
109	1.96364E+01	-2.56484E+02
110	1.98182E+01	-4.36484E+02
111	2.00000E+01	-4.[illegible]E+02
112	2.01818E+01	-4.16484E+02
[illegible]	2.03636E+01	-4.[illegible]484E+02
114	2.05455E+01	-5.56484E+02
115	2.07273E+01	-4.56484E+02
116	2.09091E+01	-2.56484E+02
117	2.10909E+01	-3.64844E+01
118	2.12727E+01	-3.64844E+01
119	2.14545E+01	-1.76484E+02
120	2.16364E+01	-2.76484E+02
121	2.18182E+01	-2.96484E+02
122	2.20000E+01	-2.56484E+02
123	2.21818E+01	-3.16484E+02
124	2.23636E+01	2.35156E+01
125	2.25455E+01	2.35156E+01
126	2.27273E+01	1.63516E+02
[illegible]	[illegible].29091E+01	[illegible]E+02
[illegible]	[illegible].30909E+01	1.[illegible]516E+02

TABLE X (Cont'd)

[illegible]	[illegible]	[illegible]
130	2.34545E+01	[illegible]
131	[illegible]	2.83516E+02
132	2,38182E+01	2.35156E+01
133	2.40000E+01	-2.56484E+02
134	2.41818E+01	-1.16484E+02
135	2.43636E+01	3.51563E+00
136	2.45455E+01	2.03516E+02
137	2.47273E+01	2.03516E+02
138	2.49091E+01	1,83516E+02
139	2,50909E+01	8,35156E+01
140	2,52727E+01	3.03516E+02
141	2.54545E+01	3.83516E+02
142	2,56364E+01	4.23516E+02
143	2,58182E+01	4.43516E+02
144	2.60000E+01	3.63516E+02
145	2.61818E+01	2.63516E+02
146	2,63636E+01	1.43516E+02
147	2,65455E+01	6.35156E+01
148	2,67273E+01	1,23516E+02
149	2.69091E+01	-7,64844E+01
150	2.70909E+01	-2.36484E+02
151	2.72727E+01	-1,96484E+02
152	2.74545E+01	-1,36484E+02
153	2.76364E+01	-7.64844E+01
154	2,78182E+01	1,23516E+02
155	2.80000E+01	2.43516E+02
156	2.81818E+01	3,03516E+02
157	2.83636E+01	2,63516E+02
158	2.85455E+01	1.23516E+02
159	2.87273E+01	3.51563E+00
160	2.89091E+01	-1,36484E+02
161	2.90909E+01	-4.76484E+02
162	2.92727E+01	-4,96484E+02
163	2,94545E+01	-1,36484E+02
164	2.96364E+01	2.03516E+02
165	2,98182E+01	1,43516E+02
166	3.00000E+01	1,23516E+02
167	3,01818E+01	2,23516E+02
168	3,03636E+01	1,83516E+02
169	3.05455E+01	3.43516E+02
170	3.07273E+01	3,23516E+02

TABLE X (Cont'd)

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
173	3.12727E+01	1.23516E+02
174	3.14545E+01	2.63516E+02
175	3.16364E+01	1.43516E+02
176	3.18182E+01	-2.16484E+02
177	3.20000E+01	-2.96484E+02
178	3.21818E+01	-3.64844E+01
179	3.23636E+01	-7.64844E+01
180	3.25455E+01	3.51563E+00
181	3.27273E+01	-1.36484E+02
182	3.29091E+01	-1.56484E+02
183	3.30909E+01	-1.76484E+02
184	3.32727E+01	6.35156E+01
185	3.34545E+01	3.63516E+02
186	3.36364E+01	1.63516E+02
187	3.38182E+01	-1.16484E+02
188	3.40000E+01	-1.64844E+01
189	3.41818E+01	2.63516E+02
190	3.43636E+01	2.83516E+02
191	3.45455E+01	2.63516E+02
192	3.47273E+01	1.83516E+02
193	3.49091E+01	6.35156E+01
194	3.50909E+01	-2.36484E+02
195	3.52727E+01	-3.16484E+02
196	3.54545E+01	-2.36484E+02
197	3.56364E+01	-5.64844E+01
198	3.58182E+01	4.35156E+01
199	3.60000E+01	2.03516E+02
200	3.61818E+01	2.63516E+02
201	3.63636E+01	2.03516E+02
202	3.65455E+01	1.43516E+02
203	3.67273E+01	1.03516E+02
204	3.69091E+01	-1.96484E+02
205	3.70909E+01	-9.64844E+01
206	3.72727E+01	-1.96484E+02
207	3.74545E+01	8.35156E+01
208	3.76364E+01	1.63516E+02
209	3.78182E+01	3.23516E+02
210	3.80000E+01	1.43516E+02
211	3.81818E+01	6.35156E+01
212	3.83636E+01	-5.64844E+01
213	3.85455E+01	-3.16484E+02
214	3.87273E+01	-3.36484E+02
[illegible]	3.89091E+01	-9.64844E+01
[illegible]	3.90909E+01	3.51563E+00

TABLE X (Cont'a)

[illegible]	.92727E+01	[illegible]
[illegible]	.94545E+01	-7.64844E+01
219	3.96364E+01	2.35156E+01
220	3.98182E+01	1.43516E+02
221	4.00000E+01	4,35156E+01
222	4.01818E+01	-7,64844E+01
223	4,03636E+01	3.51563E+00
224	4.05455E+01	8.35156E+01
225	4.07273E+01	1.63516E+02
226	4,09091E+01	1.63516E+02
227	4,10909E+01	1.03516E+02
[illegible]	4.12727E+01	1.23516E+02
229	4,14545E+01	2.23516E+02
230	4,16364E+01	1.23516E+02
231	4,18182E+01	8.35156E+01
232	4,20000E+01	1,63516E+02
233	4.21818E+01	2.03516E+02
234	4,23636E+01	1.63516E+02
235	4,25455E+01	1.03516E+02
236	4.27273E+01	1,03516E+02
237	4.29091E+01	-2.16484E+02
238	4.30909E+01	-2,16484E+02
239	4,32727E+01	8.35156E+01
240	4.34545E+01	2,35156E+01
241	4,36364E+01	1.03516E+02
242	4,38182E+01	-1.64844E+01
243	4,40000E+01	1.23516E+02
244	4.41818E+01	8,35156E+01
245	4,43636E+01	3.51563E+00
246	4,45455E+01	-7,64844E+01
247	4.47273E+01	-1,96484E+02
248	4,49091E+01	-4,56484E+02
249	4,50909E+01	-6,56484E+02
250	4,52727E+01	-5,76484E+02
251	4.54545E+01	-2,76484E+02
252	4,56364E+01	1.23516E+02
253	4,58182E+01	2,23516E+02
254	4,60000E+01	8,35156E+01
255	4.61818E+01	6.35156E+01
256	4.63636E+01	-7.64844E+01

TABLE XI

FREQUENCY DOMAIN DATA

FREQUENCY WINDOW=0 TO 2.75000E+00[Hz]
FREQUENCY INTERVAL= 2.14844E-02[Hz]

COEFF.	FREQUENCY[Hz]	REAL	IMAG	MAGNITUDE	PHASE[DEG]
DC TERM	0.00000E+00	0.00000E+00			
MAX FREQ.	2.75000E+00	1.64063E+00			
1	2.14844E-02	-5.66422E+00	3.75558E+01	3.79806E+01	98.58
2	4.29688E-02	-3.08013E+01	-2.76514E+01	4.13923E+01	-138.08
3	6.44531E-02	2.52530E+01	4.37340E+01	5.05013E+01	60.00
4	8.59375E-02	-2.67731E+01	-1.03771E+02	1.07169E+02	-104.47
5	1.07422E-01	-9.72249E+01	4.94728E+01	1.09088E+02	153.03
6	1.28906E-01	-4.04381E-01	-1.98008E+01	1.98049E+01	-91.17
7	1.50391E-01	-3.17996E+01	3.81944E+01	4.96994E+01	129.78
8	1.71875E-01	6.22003E+01	-3.24024E+01	7.01341E+01	-27.52
9	1.93359E-01	1.60624E+01	-4.56514E+01	4.83947E+01	-70.62
10	2.14844E-01	-3.48545E+01	4.23113E+01	5.48186E+01	129.48
11	2.36328E-01	4.79565E+01	8.04794E+00	4.86271E+01	9.53
12	2.57813E-01	3.00145E+01	2.77462E+01	4.08745E+01	42.75
13	2.79297E-01	-1.09342E+01	-1.82064E+01	2.12375E+01	-120.99
14	3.00781E-01	1.86397E+00	-1.25242E-01	1.86817E+00	-3.84
15	3.22266E-01	7.79157E+01	1.78681E+01	7.99382E+01	12.92
16	3.43750E-01	4.06294E+01	2.48508E+01	4.76268E+01	31.45
17	3.65234E-01	1.12258E+01	-4.68472E+01	4.81734E+01	-76.52
18	3.86719E-01	8.33142E+01	-3.20249E+00	8.33757E+01	-2.20
19	4.08203E-01	-3.78938E+01	-1.55635E+01	4.09653E+01	-157.67
20	4.29688E-01	3.54221E+01	1.61486E+01	3.89295E+01	24.51
21	4.51172E-01	2.32465E+01	1.76307E+01	2.91760E+01	37.18
22	4.72656E-01	2.12603E+01	-2.89151E+01	3.58899E+01	-53.67
23	4.94141E-01	1.21275E+01	2.76710E+01	3.02119E+01	66.33
24	5.15625E-01	-3.41449E+01	1.82663E+01	3.87238E+01	151.85
25	5.37109E-01	-4.57706E+01	-1.16202E+01	4.72226E+01	-165.75
26	5.58594E-01	1.17901E+01	2.11305E+01	2.41972E+01	60.84
27	5.80078E-01	2.17012E+00	-2.70234E+01	2.71103E+01	-85.41
28	6.01563E-01	1.88617E+00	2.44577E+01	2.45304E+01	85.59
29	6.23047E-01	-8.60129E+01	-2.10317E+01	8.85469E+01	-166.26
30	6.44531E-01	-7.32520E+01	-2.40619E+00	7.32915E+01	-178.12
31	6.66016E-01	1.26960E+00	1.80013E+01	1.80460E+01	85.97
32	6.87500E-01	-1.60826E+00	3.53621E+01	3.53986E+01	92.60
33	7.08984E-01	3.50477E+01	9.28483E+00	3.62567E+01	14.84
34	7.30469E-01	-2.55979E+01	-1.38642E+01	2.91113E+01	-151.56
35	7.51953E-01	-3.06648E+01	2.86086E+00	3.07979E+01	174.67
36	7.73438E-01	2.54924E+01	1.95338E+01	3.21159E+01	37.46
37	7.94922E-01	5.14659E+00	-1.15460E+01	1.26411E+01	-65.98
38	8.16406E-01	-1.84656E+01	-3.93144E+01	4.34350E+01	[illegible]
39	8.37891E-01	-9.91772E-01	6.17941E+00	6.25850E+00	[illegible]

TABLE XI (Cont'd)

40	[illegible]01	-6.29821E+00	-1.49896E+01	1.625[illegible]	[illegible]
41	[illegible]-01	-1.67293E+01	-1.03988E+01	1.96978E+01	-148.14
42	9.02344E-01	1.03300E+01	-3.48111E+01	3.63115E+01	-73.47
43	9.23828E-01	1.61600E+01	-5.52346E+00	1.70779E+01	-18.87
44	9.45313E-01	7.32488E+00	-1.76196E+01	1.90815E+01	-67.43
45	9.66797E-01	-1.39707E+01	-1.11046E+01	1.78464E+01	-141.52
46	9.88281E-01	-3.08244E+00	-2.65203E+01	2.66988E+01	-96.63
47	1.00977E+00	2.06500E+01	6.85130E+00	2.17569E+01	18.35
48	1.03125E+00	-2.34850E+01	-4.70353E+00	2.39513E+01	-168.67
49	1.05273E+00	8.66073E+00	-7.61692E+00	1.15337E+01	-41.33
50	1.07[illegible]E+00	1.42002E+01	1.73075E+01	2.23873E+[illegible]	[illegible]
51	[illegible]E+00	-7.46781E+00	4.24216E-02	7.46793E+[illegible]	[illegible]
52	[illegible]E+00	-1.70300E+01	-1.72601E+01	2.42474E+[illegible]	[illegible]
53	1.13867E+00	8.79392E+00	4.96266E+00	1.00976E+01	29.44
54	1.16016E+00	-1.14088E+01	1.14676E+00	1.14663E+01	174.26
55	1.18164E+00	1.48824E+01	-1.85699E+01	2.37976E+01	-51.29
56	1.20313E+00	-3.58370E+00	-5.06927E+00	6.20809E+00	-125.26
57	1.22461E+00	7.79754E+00	1.33918E+01	1.54965E+01	59.79
58	1.24609E+00	-6.40978E+00	1.30449E+01	1.45346E+01	116.17
59	1.26758E+00	4.33124E+00	1.56318E+00	4.60469E+00	19.84
60	1.28906E+00	-1.41814E+01	-1.41744E+01	2.00506E+01	-135.01
61	1.31055E+00	-3.95962E+00	2.13084E+01	2.16731E+01	100.53
62	1.33203E+00	1.19198E+01	1.70024E+01	2.07645E+01	54.97
63	1.35352E+00	1.12123E+01	-4.41696E+00	1.20509E+01	-21.50
64	1.37500E+00	-1.56250E+00	1.76563E+01	1.77253E+01	95.06
65	1.39648E+00	1.11276E+00	1.86572E+00	2.17236E+00	59.19
66	1.41797E+00	-9.10732E+00	4.87213E+00	1.03286E+01	151.85
67	1.43945E+00	-1.00859E+01	-1.11911E+01	1.50654E+01	-132.03
68	1.46094E+00	1.14018E+01	-6.32041E+00	1.30365E+01	-29.00
69	1.48242E+00	-7.39801E+00	5.73904E+00	9.36307E+00	142.20
70	1.50391E+00	-1.32563E+01	5.39112E+00	1.43106E+01	157.87
71	1.52539E+00	2.91244E+01	-1.45681E+01	3.25647E+01	-26.57
72	1.54688E+00	-3.42577E+00	-9.08342E+00	9.70795E+00	-110.66
73	1.56836E+00	-8.33438E+00	-7.19591E+00	1.10110E+01	-139.19
74	1.58984E+00	-1.58761E+00	-8.98015E+00	9.11941E+00	-100.03
75	1.61133E+00	1.32531E+00	6.09348E+00	6.23594E+00	77.73
76	1.63281E+00	-1.02109E+01	1.40944E+01	1.74045E+01	125.92
77	1.65430E+00	-4.90033E+00	1.03016E+00	5.00744E+00	168.13
78	1.67578E+00	-9.68568E+00	6.38179E+00	1.15991E+01	146.62
79	1.69727E+00	-3.55642E+00	-5.62833E+00	6.65779E+00	-122.29
80	1.71875E+00	-5.86355E+00	1.08705E+01	1.23511E+01	118.34
81	1.74023E+00	3.60779E+00	-4.30412E-01	3.63338E+00	-6.80
82	1.76172E+00	-2.93561E+00	1.91805E+00	3.50666E+00	146.84
83	1.78320E+00	4.44884E+00	1.00820E+00	4.56165E+00	12.77
84	1.80469E+00	2.43905E+00	-3.94084E+00	4.63457E+00	-58.25
85	1.82617E+00	8.13459E+00	2.99127E+00	8.71408E+00	20.08
86	1.847[illegible]E+00	-3.49144E+00	2.47859E+00	4.28177E+00	[illegible]
87	1.86[illegible]E+00	-2.28378E+00	1.37707E-01	2.28792E+00	[illegible]

TABLE XI (Cont'd)

[illegible]	[illegible]3E+00	[illegible]	[illegible]0	7.8[illegible]	[illegible]
89	1.91211E+00	[illegible]	[illegible]	3.88519E+00	-138.09
90	1.93359E+00	6.46264E+00	1.28266E+00	6.58870E+00	11.23
91	1.95508E+00	-4.13891E+00	2.32846E+00	4.74893E+00	150.64
92	1.97656E+00	2.38828E+00	-1.52256E+00	2.83232E+00	-32.52
93	1.99805E+00	5.73805E-01	-2.83475E+00	2.89224E+00	-78.56
94	2.01953E+00	6.30298E+00	-1.00312E+00	6.38231E+00	-9.04
95	2.04102E+00	-1.96648E+00	-8.57702E+00	8.79957E+00	-102.91
96	2.06250E+00	-1.82924E+00	-9.95043E+00	1.01172E+01	-100.42
97	2.08398E+00	4.43762E+00	5.45395E+00	7.03122E+00	50.87
98	2.10547E+00	6.04288E+00	-7.39588E+00	9.55068E+00	-50.75
99	2.12695E+00	-2.46920E+00	-4.37724E-01	2.50770E+00	-169.95
100	2.14844E+00	4.46415E+00	7.18980E+00	8.46297E+00	58.16
101	2.16992E+00	-2.06360E+00	-1.27429E+00	2.42534E+00	-148.30
102	2.19141E+00	-3.52992E-01	-3.59263E+00	3.60993E+00	-95.61
103	2.21289E+00	-3.43973E+00	1.72214E+00	3.84675E+00	153.40
104	2.23438E+00	2.61648E+00	2.62099E+00	3.70345E+00	45.05
105	2.25586E+00	-9.37128E+00	-1.72932E+00	9.52951E+00	-169.54
106	2.27734E+00	-1.41818E+00	3.80544E-01	1.46835E+00	164.98
107	2.29883E+00	-1.16358E+00	-4.66612E+00	4.80901E+00	-104.00
108	2.32031E+00	9.90368E+00	7.20514E-02	9.90394E+00	.42
109	2.34180E+00	-3.58951E+00	-2.74263E+00	4.517[illegible]	[illegible]
110	2.36328E+00	9.12973E+00	2.51070E+00	9.468[illegible]	[illegible]
111	2.38477E+00	2.98918E+00	-1.99324E+00	3.59279E+00	-33.70
112	2.40625E+00	5.59410E+00	-7.07516E+00	9.01952E+00	-51.67
113	2.42773E+00	2.13953E+00	1.80685E+00	2.80042E+00	40.18
114	2.44922E+00	1.17494E+01	9.78102E+00	1.52878E+01	39.78
115	2.47070E+00	-9.03355E+00	-5.61874E+00	1.06384E+01	-148.12
116	2.49219E+00	-2.74846E+00	7.99086E-01	2.86226E+00	163.79
117	2.51367E+00	1.51662E+00	3.93849E+00	4.22041E+00	68.94
118	2.53516E+00	1.67147E+00	3.14376E-01	1.70078E+00	10.65
119	2.55664E+00	1.23170E+00	-7.15676E-01	1.42452E+00	-30.16
120	2.57813E+00	5.56595E-01	3.47623E+00	3.52051E+00	80.90
121	2.59961E+00	-3.73711E+00	-2.00612E+00	4.24152E+00	-151.77
122	2.62109E+00	2.60609E-01	-8.31441E+00	8.31849E+00	-88.20
123	2.64258E+00	3.68183E+00	-1.81169E+00	4.10342E+00	-26.20
124	2.66406E+00	2.70677E+00	1.82509E+00	3.26459E+00	33.99
125	2.68555E+00	-3.81240E-01	3.62664E-01	5.26183E-01	136.43
126	2.70703E+00	-5.18660E+00	-5.73912E+00	7.73552E+00	-132.10
127	2.72852E+00	5.60483E+00	-4.03566E+00	6.90657E+00	[illegible]

TABLE XII

POWER

COEFF.	FREQ.[Hz]	POWER	( )/MAX
DC	0.00000E+00	0.00000E+00	0.000
MAX	2.75000E+00	2.69165E+00	.000
1	2.14844E-02	1.44252E+03	.121
2	4.29688E-02	1.71332E+03	.144
3	6.44531E-02	2.55038E+03	.214
4	8.59375E-02	1.14852E+04	.965
5	1.07422E-01	1.19002E+04	1.000
6	1.28906E-01	3.92235E+02	.033
7	1.50391E-01	2.47003E+03	.208
8	1.71875E-01	4.91880E+03	.413
9	1.93359E-01	2.34205E+03	.197
10	2.14844E-01	3.00508E+03	.253
11	2.36328E-01	2.36460E+03	.199
12	2.57813E-01	1.67072E+03	.140
13	2.79297E-01	4.51030E+02	.038
14	3.00781E-01	3.49006E+00	.000
15	3.22266E-01	6.39012E+03	.537
16	3.43750E-01	2.26831E+03	.191
17	3.65234E-01	2.32068E+03	.195
18	3.86719E-01	6.95151E+03	.584
19	4.08203E-01	1.67816E+03	.141
20	4.29688E-01	1.51551E+03	.127
21	4.51172E-01	8.51241E+02	.072
22	4.72656E-01	1.28808E+03	.108
23	4.94141E-01	9.12759E+02	.077
24	5.15625E-01	1.49953E+03	.126
25	5.37109E-01	2.22998E+03	.187
26	5.58594E-01	5.85507E+02	.049
27	5.80078E-01	7.34971E+02	.062
28	6.01563E-01	6.01739E+02	.051
29	6.23047E-01	7.84055E+03	.659
30	6.44531E-01	5.37164E+03	.451
31	6.66016E-01	3.25658E+02	.027
32	6.87500E-01	1.25306E+03	.105
33	7.08984E-01	1.31455E+03	.110
34	7.30469E-01	8.47470E+02	.071
35	7.51953E-01	9.48512E+02	.080
36	7.73438E-01	1.03143E+03	.087
37	7.94922E-01	1.59798E+02	.013
38	8.16406E-01	1.88660E+03	.159
39	8.37891E-01	3.91688E+01	.003

TABLE XII (Cont'd)

[illegible]	[illegible]37[illegible]	[illegible]+02	[illegible]
[illegible]	[illegible]85[illegible]	[illegible]+02	.033
42	9.02344E-01	1.31853E+03	.111
43	9.23828E-01	2.91655E+02	.025
44	9.45313E-01	3.64104E+02	.031
45	9.66797E-01	3.18494E+02	.027
46	9.88281E-01	7.12825E+02	.060
47	1.00977E+00	4.73365E+02	.040
48	1.03125E+00	5.73667E+02	.048
49	1.05273E+00	1.33026E+02	.011
50	1.07422E+00	5.01193E+02	.042
51	1.09570E+00	5.57699E+01	.005
52	1.11719E+00	5.87934E+02	.049
53	1.13867E+00	1.01961E+02	.009
54	1.16016E+00	1.31476E+0[illegible]	.011
55	1.18164E+00	5.66326E+0[illegible]	.0[illegible]8
56	1.20313E+00	3.85404E+01	.003
57	1.22461E+00	2.40141E+02	.020
58	1.24609E+00	2.11255E+02	.018
59	1.26758E+00	2.12031E+01	.002
60	1.28906E+00	4.02025E+02	.034
61	1.31055E+00	4.69725E+02	.039
62	1.33203E+00	4.31164E+02	.036
63	1.35352E+00	1.45225E+02	.012
64	1.37500E+00	3.14185E+02	.026
65	1.39648E+00	4.71914E+00	.000
66	1.41797E+00	1.06681E+02	.009
67	1.43945E+00	2.26967E+02	.019
68	1.46094E+00	1.69949E+02	.014
69	1.48242E+00	8.76672E+01	.007
70	1.50391E+00	2.04793E+02	.017
71	1.52539E+00	1.06046E+03	.089
72	1.54688E+00	9.42443E+01	.008
73	1.56836E+00	1.21243E+02	.010
74	1.58984E+00	8.31636E+01	.007
75	1.61133E+00	3.88870E+01	.003
76	1.63281E+00	3.02916E+02	.025
77	1.65430E+00	2.50745E+01	.002
78	1.67578E+00	1.34540E+02	.011
79	1.69727E+00	4.43262E+01	.004
80	1.71875E+00	1.52550E+02	.013
81	1.74023E+00	1.32014E+01	.001
82	1.76172E+00	1.22967E+01	.001
83	1.78320E+00	2.08087E+01	.002
84	1.80469E+00	2.14792E+01	.002
85	1.82617E+00	7.59352E+01	.006
86	1.84766E+00	1.83335E+01	.002
87	1.86[illegible]14E+00	5.23460E+00	.000

TABLE XII (Cont'd)

[illegible]	[illegible]E+00	[illegible]E+01	.005
89	1.91211E+00	1.50947E+01	.001
90	1.93359E+00	4.34109E+01	.004
91	1.95508E+00	2.25523E+01	.002
92	1.97656E+00	8.02206E+00	.001
93	1.99805E+00	8.36504E+00	.001
94	2.01953E+00	4.07339E+01	.003
95	2.04102E+00	7.74324E+01	.007
96	2.06250E+00	1.02357E+02	.009
97	2.08398E+00	4.94381E+01	.004
98	2.10547E+00	9.12155E+01	.008
99	2.12695E+00	6.28853E+00	.001
100	2.14844E+00	7.16219E+01	.006
101	2.16992E+00	5.88227E+00	.000
102	2.19141E+00	1.30316E+01	.001
103	2.21289E+00	1.47975E+01	.001
104	2.23438E+00	1.37156E+01	.001
105	2.25586E+00	9.08115E+01	.008
106	2.27734E+00	2.15606E+00	.000
107	2.29883E+00	2.31266E+01	.002
108	2.32031E+00	9.80881E+01	.008
109	2.34180E+00	2.04066E+01	.002
110	2.36328E+00	8.96555E+01	[illegible]
111	2.38477E+00	1.29082E+01	.001
112	2.40625E+00	8.13518E+01	.007
113	2.42773E+00	7.84233E+00	.001
114	2.44922E+00	2.33717E+02	.020
115	2.47070E+00	1.13175E+02	.010
116	2.49219E+00	8.19256E+00	.001
117	2.51367E+00	1.78119E+01	.001
118	2.53516E+00	2.89265E+00	.000
119	2.55664E+00	2.02927E+00	.000
120	2.57813E+00	1.23940E+01	.001
121	2.59961E+00	1.79905E+01	.002
122	2.62109E+00	6.91973E+01	.006
123	2.64258E+00	1.68381E+01	.001
124	2.66406E+00	1.06576E+01	.001
125	2.68555E+00	2.76869E-01	.000
126	2.70703E+00	5.98383E+01	.005
127	2.72852E+00	4.77007E+01	.004

TABLE XIII

frequency	$Y_1 * Y_2$ (note 1)
0214844	170816.0058
0429688	419365.90976
0644531	87908.283106
.0859375	1046081.20416
.107422	6997900.7098
.128906	355270.381365
.150391	300444.56908
.171875	540399.0432
.193359	87983.558145
.214844	1836254.134
.236328	305844.4578
.257813	130598.51168
.279297	36744.015907
.300781	1024.98525122
.322266	338338.961664
.34375	255985.58843
.365234	421867.13448
.386719	807702.89841
.408203	27082.313896
.429688	35980.480665
.451172	27949.3064976
.472656	86715.47772
.494141	41870.1721239
.515625	57780.489772
.537109	238636.84974
.558594	13872.5930031
.580078	36333.6588705
.601563	29025.6629257
.623047	102315.257225
.644531	194832.605784
.666016	7161.6102096
.6875	58221.302698
.708984	32756.614175
.730469	34932.204918
.751953	3771.41650368
.773438	99150.953328
.794922	737.41503666
.816406	3203.390202
.837891	216.88352092
.859375	5909.1537505

note 1: $Y_1 * Y_2$ = magnitude of 15000 rpm in the power spectrum times magnitude of 19000 rpm in the power spectrum

TABLE XIV

frequency	referred magnitude (note 1)
.0214844	2.44096069498E-02
.0429688	5.99273878197E-02
.0644531	1.25620935123E-02
.0859375	.149485002366
.107422	1
.128906	5.07681369168E-02
.150391	4.29335284308E-02
.171875	7.72230223906E-02
.193359	1.25728503152E-02
.214844	.262400712749
.236328	4.37051725201E-02
.257813	1.86625271058E-02
.279297	5.25071981309E-03
.300781	1.46470390725E-04
.322266	4.83486370691E-02
.34375	3.65303401685E-02
.365234	6.02348128281E-02
.386719	.115420742863
.408203	3.87006261150E-03
.429688	5.14161062826E-03
.451172	3.99395585285E-03
.472656	1.23916416245E-02
.494141	5.98324752811E-03
.515625	8.25683189404E-03
.537109	3.41012054381E-02
.558594	1.98239351748E-03
.580078	5.19207979325E-03
.601563	4.14776718467E-03
.623047	1.46208500903E-02
.644531	2.78415790483E-02
.666016	1.02339408725E-03
.6875	8.31982406045E-03
.708984	4.68092011210E-03
.730469	4.99181202572E-03
.751953	5.38935412216E-04
.773438	1.41686710686E-02
.794922	1.05376607534E-04
.816406	4.57764454633E-04
.837891	3.09926547852E-05
.859375	8.44418061294E-04

note 1: each Y_1*Y_2 value in Table XIII has been referred by division by the largest value computed. The largest value occurs at a frequency of .107422 HZ.

TABLE XV

DEFINITION OF COLUMN HEADINGS IN TABLES XVI TO XXXVII

SYMBOL	DEFINITION
C-DELT	Stage ΔT calculated from the measured HP.
DIFF	(DEL T) - (C-DELT)
V1	Velocity at Stator Exit Plane (ft/sec)
V2	Velocity at Rotor Exit Plane (ft/sec)
VA1	Axial Velocity at Stator Exit Plane (ft/sec)
VA2	Axial Velocity at Rotor Exit Plane (ft/sec)
VU1	Tangential Velocity at Stator Exit Plane (ft/sec)
VU2	Tangential Velocity at Rotor Exit Plane (ft/sec)
M1	Mach Number at Stator Exit Plane
MA1	Axial Mach Number at Stator Exit Plane
M2	Mach Number at Rotor Exit Plane
MA2	Axial Mach Number at Rotor Exit Plane
A1	Flow Angle at Stator Exit Plane (degrees)
A2	Flow Angle at Rotor Exit Plane (degrees)
B1	Relative Flow Angle at Rotor Inlet Plane (degrees)
B2	Relative Flow Angle at Rotor Exit Plane (degrees)

TABLE XV (Cont'd)

SYMBOL	DEFINITION
ZS or Z1	Stator Loss Coefficient
ZSTH	Theoretical Stator Loss Coefficient
ZR or Z3	Rotor Loss Coefficient
ZRTH	Theoretical Rotor Loss Coefficient
ZR*	Rotor Carry Over Loss Coefficient
ZI	Rotor Incidence Loss Coefficient
Y	After Expansion Loss Coefficient
P.R.	Pressure Ratio P_{t_o}/P_2
STPR	Stator Pressure Ratio
H.P.	Horsepower
RTM or DYNA Q	Rotor Torque (Moment) (in-lbf)
STM or STATOR Q	Stator Torque (Moment) (in-lbf)
AXF or AX FORCE	Stator Axial Force - Force Capsule (lbf)
CLF or CL FORCE	Closure Plate Force - Force Capsule (lbf)
MW-DOT	Computed Mass Flow Rate (lbm/sec)
PTO	Total Pressure (in Hg)
TTO	Total Temperature (°R)
PHD	Hood Pressure (in Hg)
P-TIP	Static Pressure at Stator Tap Tip #3 (in Hg)
P1	Computed Stator Exit Pressure (in Hg)
P-HUB	Static Pressure at Stator Tap "HUB #3" (in Hg)
P-TIP/PTO	Pressure Ratio of P_{tip}/P_{t_o}

SYMBOL	DEFINITION
P1/PTO	Pressure Ratio of P_1/P_{t_o}
P-HUB/PTO	Pressure Ratio of P_{hub}/P_{t_o}
KIS	Isentropic Head Coefficient
TURB RE	Reynold's Number at the Stator Entrance
DELT or DEL T	Temperature Difference Across the Stage = $T_{t_o} - T_{hood}$
ETA	Total to Static Efficiency
DELTA	Pressure Ratio, $\delta = \frac{P_{t_o}}{P_{ref}}$ ($P_{ref}=29.92$)
THETA	Temperature Ratio, $\theta = \frac{T_{t_o}}{T_{ref}}$ ($T_{ref} = 518.7°R$)
RHP	Referred Horsepower
RMW-DOT	Referred Computed Mass Flow Rate (lbm/sec)
RRTM	Referred Rotor Torque (Moment) (in-lbf)
RSTM	Referred Stator Torque (Moment) (in-lbf)
RN	Referred RPM (RPM)
RTH	Theoretical Degree of Reaction
REFF	Effective Degree of Reaction
RAF	Resultant Axial Force (computed) (lbf)
RPM	Rotor Speed (RPM)
P1 P2 P3 P4 P5 P6 P7 P8 P9	Pressure Ratios Corresponding to Tap Locations in Figure 6. Pressures are referred to Stator Inlet Total Pressure (P_{t_o})

TABLE XVI

TEMPERATURE DROP CALCULATED FROM THE MEASURED POWER AND MEASURED VALUES

RUN 10

PT.	H.P.	R-H.P.	RMW-DOT	TTO	DEL T	C-DEL T	DIFF
1	78.54	35.58	1.02664	636.4	119.6	125.2	-5.7
2	83.39	37.62	1.02503	635.9	130.7	132.5	-1.8
3	87.64	39.75	1.02766	636.0	136.9	139.7	-2.8
4	90.08	40.69	1.02446	635.5	140.5	143.3	-2.8
5	92.44	41.82	1.02408	634.6	142.2	147.1	-4.9
6	94.85	42.92	1.02434	634.6	145.4	150.9	-5.6
7	96.83	43.84	1.02544	634.2	148.9	153.9	-5.0
8	98.35	44.53	1.02482	634.2	146.5	156.4	-10.0
9	102.53	45.69	1.02482	634.4	151.3	160.6	-9.3

RUN 11

PT.	H.P.	R-H.P.	RMW-DOT	TTO	DEL T	C-DEL T	DIFF
1	98.62	35.58	1.02707	641.0	121.6	126.1	-4.4
2	104.40	37.49	1.02358	641.0	129.7	133.3	-3.6
3	107.81	39.14	1.02576	640.6	136.8	138.8	-2.0
4	112.28	40.60	1.02602	639.6	139.9	143.7	-3.8
5	115.51	41.57	1.02445	639.1	141.1	147.2	-6.2
6	117.92	42.63	1.02499	639.0	142.4	150.9	-8.5
7	119.70	43.26	1.02536	638.6	148.1	153.0	-4.9
8	121.83	44.02	1.02712	638.6	146.3	155.4	-9.1

RUN 12

PT.	H.P.	R-H.P.	RMW-DOT	TTO	DEL T	C-DEL T	DIFF
1	81.85	38.87	1.01757	574.1	97.8	124.5	-26.7
2	85.83	40.95	1.01772	572.5	101.5	130.8	-29.3
3	90.24	42.95	1.01778	571.9	103.2	137.0	-33.8
4	89.68	42.68	1.01646	571.5	104.1	136.3	-32.1
5	88.08	41.97	1.01765	571.3	106.2	133.8	-27.6
6	93.34	44.57	1.01758	570.9	107.7	142.0	-34.3

RUN 13

PT.	H.P.	R-H.P.	RMW-DOT	TTO	DEL T	C-DEL T	DIFF
1	79.95	37.75	1.01942	574.3	90.5	120.8	-30.3
2	84.17	39.94	1.02128	572.8	99.9	127.2	-27.3
3	87.13	41.30	1.02258	572.9	96.6	131.4	-34.8
4	88.76	42.17	1.02399	573.1	96.2	134.0	-37.8
5	89.69	42.65	1.02403	573.3	97.3	135.6	-38.3
6	91.25	43.31	1.02368	573.4	96.7	137.7	-41.0
7	92.76	43.95	1.02320	574.2	96.3	140.0	-43.8
8	91.87	43.51	1.02239	574.5	98.7	138.8	-40.1

RUN 14

PT.	H.P.	R-H.P.	RMW-DOT	TTO	DEL T	C-DEL T	DIFF
1	79.91	37.16	1.02273	603.1	117.5	124.4	-6.9
2	85.42	39.45	1.02051	602.2	120.2	132.2	-11.9
3	87.89	40.67	1.02228	602.2	121.0	136.0	-15.0
4	89.39	41.38	1.02081	602.0	123.4	138.5	-15.1
5	92.64	42.74	1.02100	602.0	124.6	143.1	-18.4
6	92.69	43.02	1.02172	602.0	123.3	143.9	-20.6
7	93.35	43.20	1.02208	602.5	123.8	144.6	-20.8
8	94.63	43.74	1.02258	602.5	121.6	146.3	-24.8

RUN 15

PT.	H.P.	R-H.P.	RMW-DOT	TTO	DEL T	C-DEL T	DIFF
1	84.34	36.92	1.02403	670.5	136.5	137.3	-0.8
2	87.97	38.49	1.02587	673.0	143.2	143.4	-0.2
3	91.40	40.02	1.02753	674.3	149.3	149.1	0.2
4	94.05	41.17	1.02811	675.3	152.0	153.5	-1.6
5	98.24	42.82	1.02575	676.3	154.9	160.3	-5.4
6	100.57	43.79	1.02652	676.9	162.2	164.0	-1.8
7	102.66	44.88	1.02918	677.2	162.4	167.7	-5.2
8	102.72	44.92	1.02994	677.3	163.0	167.7	-4.7

TABLE XVII

TTR INPUT DATA

PORT NO. / RUN PT.		1	2	3	4	5	6
10	1	0.000002	0.001361	0.006318	0.006112	0.004095	0.004034
10	2	0.000002	0.001361	0.006361	0.006153	0.004119	0.004073
10	3	0.000001	0.001361	0.006317	0.006111	0.004091	0.004032
10	4	0.000001	0.001361	0.006360	0.006151	0.004115	0.004070
10	5	0.000001	0.001360	0.006343	0.006136	0.004112	0.004065
10	6	0.000001	0.001360	0.006353	0.006144	0.004109	0.004063
10	7	0.000000	0.001360	0.006350	0.006140	0.004108	0.004058
10	8	0.000001	0.001360	0.006346	0.006139	0.004107	0.004061
10	9	0.000001	0.001360	0.006517	0.006304	0.004233	0.004189

PORT NO. / RUN PT.		7	8	9	10	11	12
10	1	0.004039	0.003980	0.004039	0.004028	-0.001739	-0.002431
10	2	0.004078	0.004015	0.004079	0.004068	-0.001756	-0.002372
10	3	0.004037	0.003978	0.004039	0.004029	-0.001748	-0.002305
10	4	0.004075	0.004014	0.004077	0.004065	-0.001762	-0.002244
10	5	0.004069	0.004007	0.004069	0.004058	-0.001761	-0.002186
10	6	0.004069	0.004007	0.004069	0.004058	-0.001762	-0.002119
10	7	0.004064	0.004005	0.004064	0.004052	-0.001764	-0.002035
10	8	0.004067	0.004004	0.004066	0.004054	-0.001763	-0.001995
10	9	0.004196	0.004134	0.004196	0.004185	-0.001805	-0.001791

PORT NO. / RUN PT.		13	14	15	16	17	18
10	1	-0.000506	-0.002046	-0.001789	-0.002358	-0.002486	0.001275
10	2	-0.000491	-0.002036	-0.001778	-0.002263	-0.002436	0.001299
10	3	-0.000505	-0.002044	-0.001787	-0.002109	-0.002380	0.001274
10	4	-0.000491	-0.002037	-0.001777	-0.001944	-0.002329	0.001303
10	5	-0.000494	-0.002038	-0.001777	-0.001769	-0.002279	0.001302
10	6	-0.000492	-0.002038	-0.001775	-0.001534	-0.002212	0.001304
10	7	-0.000493	-0.002039	-0.001774	-0.001460	-0.002148	0.001305
10	8	-0.000492	-0.002038	-0.001770	-0.001385	-0.002098	0.001309
10	9	-0.000435	-0.002006	-0.001728	-0.001191	-0.001970	0.001401

PORT NO. / RUN PT.		19	20	21	22	23	24
10	1	-0.000056	-0.002433	-0.002438	0.000147	-0.001675	-0.001808
10	2	-0.000048	-0.002421	-0.002382	0.000164	-0.001611	-0.001650
10	3	-0.000062	-0.002415	-0.002311	0.000143	-0.001547	-0.001558
10	4	-0.000049	-0.002405	-0.002253	0.000166	-0.001459	-0.001460
10	5	-0.000058	-0.002401	-0.002185	0.000160	-0.001355	-0.001375
10	6	-0.000062	-0.002391	-0.002119	0.000160	-0.001275	-0.001284
10	7	-0.000061	-0.002381	-0.002046	0.000159	-0.001209	-0.001193
10	8	-0.000061	-0.002366	-0.001997	0.000159	-0.001171	-0.001113
10	9	-0.000016	-0.002328	-0.001777	0.000230	-0.001021	-0.000899

PORT NO. / RUN PT.		25	26	27	28	29	30
10	1	0.000001	0.001360	0.004064	-0.002432	-0.001817	-0.001588
10	2	0.000001	0.001361	0.004082	-0.002378	-0.001733	-0.001501
10	3	0.000000	0.001360	0.004039	-0.002306	-0.001640	-0.001413
10	4	0.000001	0.001360	0.004089	-0.002246	-0.001542	-0.001321
10	5	0.000000	0.001359	0.004080	-0.002182	-0.001436	-0.001211
10	6	0.000001	0.001361	0.004087	-0.002113	-0.001347	-0.001124
10	7	0.000001	0.001360	0.004063	-0.002042	-0.001261	-0.001075
10	8	0.000000	0.001360	0.004065	-0.001972	-0.001199	-0.001026
10	9	0.000001	0.001360	0.004200	-0.001786	-0.001017	-0.000883

PORT NO. RUN	PT.	31	32	33	34	35	36
10	1	-0.001592	-0.001480	-0.001479	-0.001550	-0.001509	-0.001401
10	2	-0.001513	-0.001415	-0.001405	-0.001477	-0.001476	-0.001415
10	3	-0.001443	-0.001362	-0.001384	-0.001455	-0.001419	-0.001381
10	4	-0.001371	-0.001313	-0.001347	-0.001465	-0.001451	-0.001374
10	5	-0.001303	-0.001312	-0.001323	-0.001434	-0.001437	-0.001366
10	6	-0.001238	-0.001229	-0.001278	-0.001432	-0.001469	-0.001401
10	7	-0.001195	-0.001182	-0.001210	-0.001374	-0.001414	-0.001387
10	8	-0.001151	-0.001136	-0.001166	-0.001345	-0.001387	-0.001370
10	9	-0.001011	-0.001031	-0.001057	-0.001253	-0.001325	-0.001348

PORT NO. RUN	PT.	37	38	39	40	41	42
10	1	-0.001706	-0.001763	-0.001730	-0.001759	-0.001744	-0.001754
10	2	-0.001750	-0.001787	-0.001736	-0.001763	-0.001771	-0.001776
10	3	-0.001733	-0.001775	-0.001738	-0.001759	-0.001758	-0.001769
10	4	-0.001736	-0.001799	-0.001766	-0.001785	-0.001785	-0.001784
10	5	-0.001722	-0.001792	-0.001763	-0.001783	-0.001792	-0.001787
10	6	-0.001719	-0.001794	-0.001753	-0.001788	-0.001795	-0.001793
10	7	-0.001729	-0.001797	-0.001741	-0.001784	-0.001793	-0.001792
10	8	-0.001733	-0.001845	-0.001735	-0.001779	-0.001785	-0.001788
10	9	-0.001783	-0.001954	-0.001804	-0.001834	-0.001834	-0.001836

PORT NO. RUN	PT.	43	44	45	46	47	48
10	1	-0.001738	-0.001732	-0.001759	-0.001760	0.000001	0.000001
10	2	-0.001761	-0.001751	-0.001767	-0.001766	0.000001	0.000001
10	3	-0.001758	-0.001748	-0.001751	-0.001750	0.000002	0.000001
10	4	-0.001778	-0.001775	-0.001770	-0.001771	0.000001	0.000000
10	5	-0.001771	-0.001772	-0.001766	-0.001766	0.000000	0.000001
10	6	-0.001778	-0.001774	-0.001771	-0.001771	0.000000	0.000000
10	7	-0.001777	-0.001774	-0.001771	-0.001769	0.000001	0.000002
10	8	-0.001771	-0.001771	-0.001766	-0.001766	0.000000	0.000000
10	9	-0.001816	-0.001817	-0.001816	-0.001816	0.000001	0.000000

CHANNEL RUN	PT	0	1	2	3	4	RPM
10	1	0.005023	0.004720	0.004269	0.003491	0.004200	11077
10	2	0.005005	0.004705	0.004253	0.003460	0.004184	12057
10	3	0.005031	0.004724	0.004246	0.003463	0.004188	13089
10	4	0.005011	0.004712	0.004228	0.003475	0.004174	14078
10	5	0.004989	0.004689	0.004198	0.003459	0.004146	15051
10	6	0.004990	0.004693	0.004197	0.003474	0.004145	16045
10	7	0.004983	0.004683	0.004195	0.003483	0.004134	16935
10	8	0.004988	0.004686	0.004196	0.003486	0.004133	18384
10	9	0.005020	0.004707	0.004203	0.003507	0.004140	19346

CHANNEL RUN	PT	5	6	20	21	23	RPM
10	1	0.000696	0.002843	-0.001219	0.000590	0.004469	11077
10	2	0.000365	0.002711	-0.001062	0.000724	0.004359	12057
10	3	0.000194	0.002701	-0.000909	0.000862	0.004220	13089
10	4	0.000080	0.002645	-0.000769	0.001025	0.004033	14078
10	5	0.000007	0.002528	-0.000633	0.001240	0.003871	15051
10	6	-0.000082	0.002755	-0.000465	0.001257	0.003726	16045
10	7	-0.000191	0.002939	-0.000292	0.001349	0.003604	16935
10	8	-0.000124	0.002974	-0.000035	0.001657	0.003372	18384
10	9	-0.000252	0.002957	0.000232	0.001873	0.003340	19346

CHANNEL RUN	PT	23	24	25	26	27	RPM
10	1	0.004469	0.003610	0.003004	0.007686	0.002094	11077
10	2	0.004359	0.003587	0.003004	0.007711	0.002100	12057
10	3	0.004220	0.003541	0.002999	0.007708	0.002098	13089
10	4	0.004033	0.003494	0.002998	0.007705	0.002097	14078
10	5	0.003871	0.003451	0.002998	0.007697	0.002096	15051
10	6	0.003726	0.003397	0.002998	0.007692	0.002095	16045
10	7	0.003604	0.003351	0.002999	0.007698	0.002097	16935
10	8	0.003372	0.003273	0.002998	0.007694	0.002096	18384
10	9	0.003340	0.003301	0.002998	0.007814	0.002131	19346

TABLE XVIII

TTR INPUT DATA

PORT NO. RUN PT.		1	2	3	4	5	6
11	1	0.000000	0.001360	0.006737	0.006421	0.006151	0.006081
11	2	0.000000	0.001360	0.006778	0.006461	0.006183	0.006130
11	3	0.000000	0.001359	0.006671	0.006360	0.006073	0.006019
11	4	0.000000	0.001359	0.006729	0.006415	0.006143	0.006073
11	5	0.000001	0.001359	0.006779	0.006462	0.006183	0.006125
11	6	0.000000	0.001357	0.006729	0.006415	0.006143	0.006076
11	7	0.000001	0.001356	0.006740	0.006424	0.006150	0.006090
11	8	0.000000	0.001353	0.006745	0.006430	0.006151	0.006091

PORT NO. RUN PT.		7	8	9	10	11	12
11	1	0.006087	0.006008	0.006090	0.006075	-0.001151	-0.002017
11	2	0.006134	0.006050	0.006136	0.006122	-0.001161	-0.001932
11	3	0.006027	0.005943	0.006028	0.006012	-0.001142	-0.001851
11	4	0.006078	0.005990	0.006079	0.006065	-0.001157	-0.001768
11	5	0.006132	0.006029	0.006134	0.006119	-0.001173	-0.001694
11	6	0.006083	0.005991	0.006088	0.006072	-0.001160	-0.001611
11	7	0.006096	0.005974	0.006102	0.006088	-0.001165	-0.001508
11	8	0.006095	0.005999	0.006096	0.006080	-0.001165	-0.001408

PORT NO. RUN PT.		13	14	15	16	17	18
11	1	0.000395	-0.001536	-0.001222	-0.001828	-0.002083	0.002565
11	2	0.000410	-0.001528	-0.001213	-0.001654	-0.002012	0.002594
11	3	0.000368	-0.001553	-0.001239	-0.001396	-0.001941	0.002536
11	4	0.000392	-0.001538	-0.001226	-0.001197	-0.001877	0.002572
11	5	0.000415	-0.001525	-0.001209	-0.001015	-0.001819	0.002609
11	6	0.000396	-0.001536	-0.001219	-0.000757	-0.001748	0.002587
11	7	0.000402	-0.001535	-0.001213	-0.000678	-0.001648	0.002601
11	8	0.000404	-0.001532	-0.001208	-0.000576	-0.001555	0.002610

PORT NO. RUN PT.		19	20	21	22	23	24
11	1	0.000874	-0.001989	-0.002024	0.001236	-0.001027	-0.001175
11	2	0.000884	-0.001972	-0.001937	0.001254	-0.000942	-0.001068
11	3	0.000853	-0.001964	-0.001851	0.001208	-0.000864	-0.000908
11	4	0.000863	-0.001947	-0.001778	0.001234	-0.000751	-0.000813
11	5	0.000872	-0.001929	-0.001700	0.001263	-0.000615	-0.000686
11	6	0.000855	-0.001933	-0.001619	0.001240	-0.000497	-0.000568
11	7	0.000863	-0.001922	-0.001505	0.001247	-0.000416	-0.000412
11	8	0.000860	-0.001907	-0.001393	0.001246	-0.000340	-0.000312

PORT NO. RUN PT.		25	26	27	28	29	30
11	1	0.000001	0.001360	0.006101	-0.002019	-0.001221	-0.000940
11	2	0.000001	0.001359	0.006134	-0.001941	-0.001118	-0.000831
11	3	0.000002	0.001360	0.006058	-0.001850	-0.001007	-0.000725
11	4	0.000001	0.001359	0.006094	-0.001776	-0.000892	-0.000611
11	5	0.000002	0.001359	0.006153	-0.001699	-0.000768	-0.000481
11	6	0.000002	0.001358	0.006111	-0.001614	-0.000642	-0.000370
11	7	0.000002	0.001355	0.006113	-0.001510	-0.000527	-0.000302
11	8	0.000002	0.001354	0.006113	-0.001400	-0.000432	-0.000220

PORT NO. RUN	PT.	31	32	33	34	35	36
11	1	-0.000983	-0.000852	-0.000830	-0.000915	-0.000866	-0.000709
11	2	-0.000871	-0.000751	-0.000728	-0.000814	-0.000824	-0.000738
11	3	-0.000782	-0.000675	-0.000694	-0.000785	-0.000755	-0.000699
11	4	-0.000701	-0.000609	-0.000653	-0.000788	-0.000778	-0.000668
11	5	-0.000610	-0.000577	-0.000589	-0.000719	-0.000771	-0.000670
11	6	-0.000522	-0.000503	-0.000583	-0.000767	-0.000821	-0.000680
11	7	-0.000457	-0.000417	-0.000465	-0.000655	-0.000738	-0.000682
11	8	-0.000384	-0.000345	-0.000389	-0.000610	-0.000718	-0.000651

PORT NO. RUN	PT.	37	38	39	40	41	42
11	1	-0.001102	-0.001193	-0.001137	-0.001167	-0.001151	-0.001164
11	2	-0.001151	-0.001225	-0.001138	-0.001172	-0.001181	-0.001185
11	3	-0.001135	-0.001210	-0.001134	-0.001168	-0.001165	-0.001181
11	4	-0.001140	-0.001230	-0.001152	-0.001184	-0.001182	-0.001186
11	5	-0.001131	-0.001256	-0.001167	-0.001198	-0.001205	-0.001204
11	6	-0.001116	-0.001246	-0.001156	-0.001197	-0.001201	-0.001200
11	7	-0.001141	-0.001268	-0.001144	-0.001192	-0.001200	-0.001200
11	8	-0.001142	-0.001278	-0.001140	-0.001186	-0.001193	-0.001196

PORT NO. RUN	PT.	43	44	45	46	47	48
11	1	-0.001158	-0.001142	-0.001177	-0.001178	0.000000	0.000000
11	2	-0.001176	-0.001157	-0.001176	-0.001176	0.000000	0.000000
11	3	-0.001171	-0.001154	-0.001158	-0.001158	0.000000	0.000000
11	4	-0.001181	-0.001173	-0.001169	-0.001169	0.000000	0.000000
11	5	-0.001191	-0.001189	-0.001182	-0.001181	0.000000	0.000000
11	6	-0.001184	-0.001180	-0.001173	-0.001173	0.000000	0.000000
11	7	-0.001184	-0.001182	-0.001175	-0.001175	0.000000	0.000000
11	8	-0.001178	-0.001178	-0.001171	-0.001170	0.000000	0.000000

CHANNEL RUN	PT	0	1	2	3	4	RPM
11	1	0.005132	0.004811	0.004403	0.003593	0.004339	11129
11	2	0.005129	0.004809	0.004398	0.003591	0.004338	12155
11	3	0.005112	0.004800	0.004379	0.003592	0.004327	13123
11	4	0.005084	0.004771	0.004349	0.003584	0.004296	14027
11	5	0.005091	0.004770	0.004334	0.003600	0.004281	15000
11	6	0.005079	0.004767	0.004329	0.003602	0.004278	15829
11	7	0.005074	0.004759	0.004329	0.003620	0.004267	16862
11	8	0.005077	0.004762	0.004328	0.003635	0.004266	18017

CHANNEL RUN	PT	5	6	20	21	23	RPM
11	1	0.000769	0.002750	-0.001523	0.000730	0.005585	11129
11	2	0.000540	0.002669	-0.001348	0.000883	0.005413	12155
11	3	0.000327	0.002740	-0.001183	0.001099	0.005178	13123
11	4	0.000211	0.002602	-0.000988	0.001273	0.005045	14027
11	5	0.000164	0.002567	-0.000802	0.001556	0.004853	15000
11	6	0.000124	0.002725	-0.000655	0.001734	0.004695	15829
11	7	-0.000044	0.002918	-0.000391	0.001764	0.004474	16862
11	8	0.000004	0.002978	-0.000082	0.002010	0.004262	18017

CHANNEL		23	24	25	26	27	RPM
RUN	PT						
11	1	0.005585	0.004510	0.002998	0.008009	0.003185	11129
11	2	0.005413	0.004464	0.002998	0.008001	0.003181	12155
11	3	0.005178	0.004360	0.002998	0.007944	0.003157	13123
11	4	0.005045	0.004342	0.002997	0.007984	0.003175	14027
11	5	0.004853	0.004300	0.002997	0.008006	0.003186	15000
11	6	0.004695	0.004229	0.002998	0.007978	0.003174	15829
11	7	0.004474	0.004158	0.002997	0.007980	0.003176	16862
11	8	0.004262	0.004099	0.002998	0.008000	0.003188	18017

TABLE XIX

TTR INPUT DATA

PORT NO. RUN	PT.	1	2	3	4	5	6
12	1	0.000000	0.001358	0.006216	0.006009	0.004118	0.004078
12	2	0.000000	0.001357	0.006178	0.005972	0.004103	0.004047
12	3	0.000000	0.001358	0.006215	0.006007	0.004121	0.004078
12	4	0.000000	0.001357	0.006209	0.006001	0.004120	0.004078
12	5	0.000000	0.001357	0.006203	0.005995	0.004114	0.004069
12	6	0.000000	0.001357	0.006182	0.005974	0.004102	0.004054

PORT NO. RUN	PT.	7	8	9	10	11	12
12	1	0.004082	0.004022	0.004083	0.004071	-0.001762	-0.002237
12	2	0.004054	0.003996	0.004056	0.004044	-0.001760	-0.002107
12	3	0.004082	0.004016	0.004081	0.004070	-0.001759	-0.001882
12	4	0.004083	0.004019	0.004084	0.004070	-0.001763	-0.001799
12	5	0.004075	0.004011	0.004076	0.004065	-0.001762	-0.001665
12	6	0.004061	0.003999	0.004061	0.004051	-0.001761	-0.001591

PORT NO. RUN	PT.	13	14	15	16	17	18
12	1	-0.000490	-0.001939	-0.001564	-0.002007	-0.002314	0.001328
12	2	-0.000501	-0.001951	-0.001581	-0.001808	-0.002205	0.001311
12	3	-0.000488	-0.001946	-0.001567	-0.001352	-0.002002	0.001329
12	4	-0.000483	-0.001942	-0.001549	-0.001237	-0.001941	0.001333
12	5	-0.000484	-0.001952	-0.001563	-0.001032	-0.001841	0.001331
12	6	-0.000491	-0.001958	-0.001562	-0.000849	-0.001772	0.001321

PORT NO. RUN	PT.	19	20	21	22	23	24
12	1	-0.000041	-0.002180	-0.002239	0.000194	-0.001210	-0.001461
12	2	-0.000066	-0.002189	-0.002113	0.000178	-0.001109	-0.001312
12	3	-0.000053	-0.002164	-0.001874	0.000194	-0.000936	-0.001031
12	4	-0.001753	-0.002152	-0.001816	0.000196	-0.000883	-0.000981
12	5	-0.001767	-0.002149	-0.001689	0.000193	-0.000803	-0.000935
12	6	-0.001765	-0.002140	-0.001580	0.000185	-0.000743	-0.000770

PORT NO. RUN	PT.	25	26	27	28	29	30
12	1	0.000000	0.001358	0.004092	-0.002234	-0.001540	-0.001280
12	2	0.000000	0.001357	0.004055	-0.002116	-0.001378	-0.001092
12	3	0.000000	0.001357	0.004079	-0.001865	-0.001090	-0.000878
12	4	0.000000	0.001357	0.004081	-0.001807	-0.001025	-0.000814
12	5	0.000000	0.001357	0.004077	-0.001746	-0.000971	-0.000752
12	6	-0.000001	0.001357	0.004056	-0.001579	-0.000846	-0.000663

PORT NO. RUN	PT.	31	32	33	34	35	36
12	1	-0.001271	-0.001237	-0.001287	-0.001365	-0.001365	-0.001301
12	2	-0.001168	-0.001171	-0.001239	-0.001354	-0.001404	-0.001313
12	3	-0.000983	-0.000996	-0.001126	-0.001316	-0.001399	-0.001319
12	4	-0.000922	-0.000959	-0.001078	-0.001286	-0.001375	-0.001319
12	5	-0.000860	-0.000918	-0.001033	-0.001247	-0.001351	-0.001319
12	6	-0.000769	-0.000857	-0.000970	-0.001191	-0.001299	-0.001309

PORT NO.		37	38	39	40	41	42
RUN	PT.						
12	1	-0.001745	-0.001774	-0.001722	-0.001760	-0.001791	-0.001786
12	2	-0.001717	-0.001779	-0.001719	-0.001765	-0.001771	-0.001767
12	3	-0.001735	-0.001819	-0.001750	-0.001804	-0.001792	-0.001789
12	4	-0.001746	-0.001833	-0.001741	-0.001724	-0.001791	-0.001793
12	5	-0.001760	-0.001851	-0.001746	-0.001778	-0.001802	-0.001798
12	6	-0.001767	-0.001875	-0.001763	-0.001777	-0.001767	-0.001796

PORT NO.		43	44	45	46	47	48
RUN	PT.						
12	1	-0.001778	-0.001764	-0.001776	-0.001776	0.000000	0.000000
12	2	-0.001766	-0.001760	-0.001756	-0.001757	0.000000	0.000000
12	3	-0.001776	-0.001775	-0.001769	-0.001769	0.000000	0.000000
12	4	-0.001773	-0.001775	-0.001770	-0.001770	0.000000	-0.000001
12	5	-0.001774	-0.001776	-0.001772	-0.001773	0.000000	0.000000
12	6	-0.001768	-0.001771	-0.001770	-0.001770	0.000000	0.000000

CHANNEL		0	1	2	3	4	RPM
RUN	PT						
12	1	0.002623	0.002555	0.002427	0.001847	0.002349	12214
12	2	0.002638	0.002545	0.002366	0.001785	0.002302	13817
12	3	0.002667	0.002554	0.002347	0.001802	0.002284	16003
12	4	0.002677	0.002561	0.002337	0.001816	0.002273	16964
12	5	0.002642	0.002546	0.002326	0.001821	0.002266	17755
12	6	0.002636	0.002534	0.002308	0.001812	0.002255	19046

CHANNEL		5	6	20	21	23	RPM
RUN	PT						
12	1	-0.000440	0.001369	-0.000732	0.000877	0.004223	12214
12	2	-0.000587	0.001461	-0.000469	0.001187	0.003915	13817
12	3	-0.000650	0.001300	0.000069	0.001545	0.003554	16003
12	4	-0.000686	0.001271	0.000277	0.001808	0.003332	16964
12	5	-0.000749	0.001365	0.000467	0.002026	0.003127	17755
12	6	-0.000801	0.001373	0.000727	0.002255	0.003089	19046

CHANNEL		23	24	25	26	27	RPM
RUN	PT						
12	1	0.004223	0.003506	0.002997	0.007599	0.002080	12214
12	2	0.003915	0.003415	0.002998	0.007577	0.002078	13817
12	3	0.003554	0.003287	0.002997	0.007594	0.002088	16003
12	4	0.003332	0.003207	0.002998	0.007589	0.002088	16964
12	5	0.003127	0.003151	0.002998	0.007593	0.002088	17755
12	6	0.003089	0.003104	0.002998	0.007584	0.002085	19046

TABLE XX

TTR INPUT DATA

PORT NO. RUN	PT.	1	2	3	4	5	6
13	1	-0.000002	0.001353	0.006283	0.006072	0.004143	0.004104
13	2	-0.000001	0.001353	0.006262	0.006053	0.004141	0.004091
13	3	-0.000002	0.001353	0.006281	0.006070	0.004141	0.004097
13	4	-0.000002	0.001353	0.006274	0.006065	0.004137	0.004091
13	5	-0.000001	0.001353	0.006256	0.006045	0.004130	0.004076
13	6	-0.000003	0.001353	0.006268	0.006059	0.004138	0.004088
13	7	0.000000	0.001355	0.006281	0.006069	0.004140	0.004096
13	8	0.000000	0.001353	0.006260	0.006051	0.004129	0.004081

PORT NO. RUN	PT.	7	8	9	10	11	12
13	1	0.004111	0.000007	0.004107	0.004096	-0.001778	-0.002225
13	2	0.004095	0.004002	0.004096	0.004083	-0.001757	-0.002173
13	3	0.004102	0.004008	0.004103	0.004092	-0.001773	-0.002098
13	4	0.004097	0.003930	0.004097	0.004086	-0.001772	-0.002017
13	5	0.004082	0.003951	0.004084	0.004073	-0.001772	-0.001895
13	6	0.004093	0.003968	0.004096	0.004086	-0.001778	-0.001778
13	7	0.004103	0.003983	0.004104	0.004092	-0.001779	-0.001628
13	8	0.004087	0.000008	0.004083	0.004071	-0.001776	-0.001532

PORT NO. RUN	PT.	13	14	15	16	17	18
13	1	-0.000483	-0.001942	-0.001521	-0.001939	-0.002309	0.001354
13	2	-0.000489	-0.001978	-0.001599	-0.001887	-0.002260	0.001348
13	3	-0.000486	-0.001971	-0.001586	-0.001715	-0.002198	0.001353
13	4	-0.000489	-0.001979	-0.001593	-0.001513	-0.002130	0.001349
13	5	-0.000492	-0.001949	-0.001510	-0.001341	-0.002019	0.001340
13	6	-0.000486	-0.001958	-0.001542	-0.001185	-0.001933	0.001352
13	7	-0.000483	-0.001972	-0.001562	-0.000909	-0.001817	0.001356
13	8	-0.000488	-0.001952	-0.001482	-0.000595	-0.001717	0.001349

PORT NO. RUN	PT.	19	20	21	22	23	24
13	1	-0.001774	-0.002184	-0.002230	0.000189	-0.001204	-0.001483
13	2	-0.001754	-0.002211	-0.002179	0.000181	-0.001145	-0.001387
13	3	-0.001768	-0.002200	-0.002104	0.000184	-0.001075	-0.001289
13	4	-0.001772	-0.002198	-0.002019	0.000182	-0.000989	-0.001192
13	5	-0.001773	-0.002163	-0.001895	0.000176	-0.000951	-0.001067
13	6	-0.001776	-0.002157	-0.001778	0.000185	-0.000862	-0.000939
13	7	-0.001779	-0.002151	-0.001625	0.000187	-0.000731	-0.000791
13	8	-0.001781	-0.002100	-0.001522	0.000180	-0.000632	-0.000706

PORT NO. RUN	PT.	25	26	27	28	29	30
13	1	-0.000002	0.001353	0.004111	-0.002231	-0.001473	-0.001151
13	2	0.000000	0.001353	0.004102	-0.002176	-0.001450	-0.001171
13	3	0.000000	0.001354	0.004101	-0.002101	-0.001333	-0.001055
13	4	0.000000	0.001353	0.004107	-0.002016	-0.001210	-0.000959
13	5	0.000000	0.001354	0.004084	-0.001889	-0.001082	-0.000855
13	6	0.000000	0.001354	0.004113	-0.001779	-0.000988	-0.000782
13	7	-0.000001	0.001354	0.004111	-0.001626	-0.000862	-0.000671
13	8	-0.000001	0.001353	0.004100	-0.001520	-0.000694	-0.000521

PORT NO.		31	32	33	34	35	36
RUN	PT.						
13	1	-0.001219	-0.001212	-0.001238	-0.001327	-0.001318	-0.001228
13	2	-0.001216	-0.001201	-0.001275	-0.001387	-0.001316	-0.001178
13	3	-0.001149	-0.001148	-0.001221	-0.001340	-0.001338	-0.001208
13	4	-0.001074	-0.001085	-0.001174	-0.001334	-0.001352	-0.001212
13	5	-0.000979	-0.000990	-0.001094	-0.001271	-0.001319	-0.001207
13	6	-0.000895	-0.000930	-0.001037	-0.001252	-0.001324	-0.001201
13	7	-0.000778	-0.000840	-0.000957	-0.001197	-0.001284	-0.001212
13	8	-0.000655	-0.000754	-0.000911	-0.001150	-0.001292	-0.001280

PORT NO.		37	38	39	40	41	42
RUN	PT.						
13	1	-0.001672	-0.001698	-0.001722	-0.001718	-0.001738	-0.001794
13	2	-0.001747	-0.001768	-0.001756	-0.001756	-0.001752	-0.001785
13	3	-0.001734	-0.001775	-0.001770	-0.001785	-0.001778	-0.001789
13	4	-0.001710	-0.001763	-0.001763	-0.001775	-0.001776	-0.001788
13	5	-0.001727	-0.001776	-0.001760	-0.001781	-0.001778	-0.001785
13	6	-0.001763	-0.001809	-0.001765	-0.001793	-0.001777	-0.001784
13	7	-0.001787	-0.001869	-0.001782	-0.001796	-0.001776	-0.001811
13	8	-0.001784	-0.001875	-0.001777	-0.001784	-0.001786	-0.001805

PORT NO.		43	44	45	46	47	48
RUN	PT.						
13	1	-0.001775	-0.001762	-0.001784	-0.001786	-0.000003	-0.000002
13	2	-0.001777	-0.001758	-0.001765	-0.001764	0.000000	0.000000
13	3	-0.001793	-0.001785	-0.001782	-0.001782	-0.000001	-0.000002
13	4	-0.001785	-0.001778	-0.001774	-0.001774	-0.000001	-0.000001
13	5	-0.001785	-0.001782	-0.001779	-0.001778	-0.000001	0.000000
13	6	-0.001791	-0.001792	-0.001788	-0.001788	-0.000002	-0.000001
13	7	-0.001789	-0.001788	-0.001790	-0.001791	-0.000001	-0.000001
13	8	-0.001785	-0.001781	-0.001788	-0.001788	-0.000001	-0.000001

CHANNEL		0	1	2	3	4	RPM
RUN	PT						
13	1	0.002790	0.002665	0.002409	0.001833	0.002354	12085
13	2	0.002753	0.002623	0.002369	0.001807	0.002309	13081
13	3	0.002758	0.002633	0.002367	0.001805	0.002313	14070
13	4	0.002764	0.002637	0.002367	0.001805	0.002319	14995
13	5	0.002774	0.002646	0.002393	0.001843	0.002324	16044
13	6	0.002778	0.002644	0.002390	0.001857	0.002327	17032
13	7	0.002785	0.002658	0.002405	0.001881	0.002351	18953
13	8	0.002783	0.002661	0.002412	0.001912	0.002359	20009

CHANNEL		5	6	20	21	23	RPM
RUN	PT						
13	1	-0.000232	0.001177	-0.000696	0.001030	0.004170	12085
13	2	-0.000535	0.001238	-0.000606	0.001013	0.004055	13081
13	3	-0.000440	0.001104	-0.000405	0.001226	0.003903	14070
13	4	-0.000425	0.001093	-0.000231	0.001409	0.003731	14995
13	5	-0.000449	0.001310	0.000077	0.001591	0.003523	16044
13	6	-0.000431	0.001328	0.000303	0.001852	0.003376	17032
13	7	-0.000396	0.001382	0.000640	0.002253	0.003085	18953
13	8	-0.000456	0.001583	0.000863	0.002410	0.002894	20009

CHANNEL		23	24	25	26	27	RPM
RUN	PT						
13	1	0.004170	0.003489	0.003001	0.007600	0.002109	12085
13	2	0.004055	0.003451	0.003003	0.007597	0.002106	13081
13	3	0.003903	0.003421	0.003003	0.007614	0.002112	14070
13	4	0.003731	0.003366	0.003003	0.007608	0.002109	14995
13	5	0.003523	0.003256	0.003003	0.007600	0.002108	16044
13	6	0.003376	0.003216	0.003002	0.007608	0.002111	17032
13	7	0.003085	0.003074	0.003003	0.007607	0.002109	18953
13	8	0.002894	0.003025	0.003002	0.007601	0.002110	20009

TABLE XXI

TTR INPUT DATA

PORT NO.		1	2	3	4	5	6
RUN	PT.						
14	1	-0.000003	0.001350	0.006251	0.006044	0.004080	0.004025
14	2	0.000001	0.001363	0.006339	0.006131	0.004144	0.004099
14	3	0.000000	0.001362	0.006322	0.006114	0.004135	0.004083
14	4	0.000001	0.001363	0.006315	0.006107	0.004133	0.004085
14	5	0.000000	0.001362	0.006357	0.006147	0.004154	0.004109
14	6	0.000001	0.001361	0.006303	0.006092	0.004115	0.004065
14	7	0.000000	0.001362	0.006322	0.006113	0.004130	0.004082
14	8	0.000002	0.001362	0.006338	0.006130	0.004139	0.004094

PORT NO.		7	8	9	10	11	12
RUN	PT.						
14	1	0.004032	0.003940	0.004033	0.004024	-0.001734	-0.002310
14	2	0.004105	0.004009	0.004106	0.004097	-0.001761	-0.002239
14	3	0.004088	0.003996	0.004091	0.004079	-0.001755	-0.002170
14	4	0.004089	0.003994	0.004091	0.004079	-0.001758	-0.002093
14	5	0.004117	0.004023	0.004118	0.004108	-0.001775	-0.002003
14	6	0.004069	0.003980	0.004071	0.004059	-0.001757	-0.001928
14	7	0.004088	0.003998	0.004090	0.004081	-0.001765	-0.001762
14	8	0.004099	0.004008	0.004098	0.004087	-0.001770	-0.001610

PORT NO.		13	14	15	16	17	18
RUN	PT.						
14	1	-0.000520	-0.002068	-0.001730	-0.001950	-0.002379	0.001279
14	2	-0.000485	-0.002046	-0.001691	-0.001853	-0.002324	0.001330
14	3	-0.000492	-0.002049	-0.001702	-0.001714	-0.002261	0.001318
14	4	-0.000493	-0.002051	-0.001708	-0.001529	-0.002211	0.001322
14	5	-0.000479	-0.002043	-0.001683	-0.001409	-0.002120	0.001342
14	6	-0.000496	-0.002055	-0.001704	-0.001293	-0.002049	0.001313
14	7	-0.000487	-0.002049	-0.001689	-0.001074	-0.001915	0.001330
14	8	-0.000481	-0.002046	-0.001653	-0.000716	-0.001788	0.001340

PORT NO.		19	20	21	22	23	24
RUN	PT.						
14	1	-0.000045	-0.002332	-0.002311	0.000135	-0.001560	-0.001588
14	2	-0.000020	-0.002302	-0.002247	0.000174	-0.001463	-0.001480
14	3	-0.000035	-0.002307	-0.002170	0.000162	-0.001384	-0.001381
14	4	-0.000041	-0.002306	-0.002104	0.000164	-0.001274	-0.001291
14	5	-0.000068	-0.002281	-0.002013	0.000181	-0.001198	-0.001189
14	6	-0.000031	-0.002284	-0.001924	0.000154	-0.001140	-0.001064
14	7	-0.000061	-0.002260	-0.001751	0.000164	-0.001027	-0.000923
14	8	-0.000124	-0.002210	-0.001616	0.000168	-0.000862	-0.000799

PORT NO.		25	26	27	28	29	30
RUN	PT.						
14	1	-0.000002	0.001351	0.004050	-0.002312	-0.001667	-0.001440
14	2	0.000000	0.001362	0.004122	-0.002244	-0.001569	-0.001330
14	3	0.000001	0.001362	0.004098	-0.002170	-0.001463	-0.001217
14	4	0.000000	0.001362	0.004094	-0.002097	-0.001340	-0.001114
14	5	0.000001	0.001362	0.004124	-0.002020	-0.001242	-0.001039
14	6	0.000002	0.001362	0.004075	-0.001919	-0.001150	-0.000980
14	7	0.000000	0.001361	0.004099	-0.001750	-0.001004	-0.000860
14	8	0.000000	0.001361	0.004099	-0.001612	-0.000841	-0.000695

PORT NO.		31	32	33	34	35	36
RUN	PT.						
14	1	-0.001448	-0.001363	-0.001338	-0.001400	-0.001406	-0.001316
14	2	-0.001350	-0.001285	-0.001300	-0.001388	-0.001371	-0.001298
14	3	-0.001287	-0.001239	-0.001251	-0.001356	-0.001410	-0.001303
14	4	-0.001249	-0.001221	-0.001239	-0.001342	-0.001380	-0.001296
14	5	-0.001165	-0.001112	-0.001153	-0.001286	-0.001387	-0.001320
14	6	-0.001110	-0.001071	-0.001085	-0.001259	-0.001328	-0.001291
14	7	-0.000975	-0.000942	-0.000973	-0.001195	-0.001281	-0.001266
14	8	-0.000806	-0.000754	-0.000828	-0.001060	-0.001188	-0.001208

PORT NO.		37	38	39	40	41	42
RUN	PT.						
14	1	-0.001708	-0.001693	-0.001721	-0.001713	-0.001731	-0.001773
14	2	-0.001738	-0.001734	-0.001756	-0.001766	-0.001752	-0.001795
14	3	-0.001704	-0.001725	-0.001746	-0.001758	-0.001760	-0.001788
14	4	-0.001705	-0.001726	-0.001734	-0.001752	-0.001756	-0.001780
14	5	-0.001727	-0.001765	-0.001750	-0.001774	-0.001775	-0.001799
14	6	-0.001737	-0.001762	-0.001725	-0.001749	-0.001756	-0.001778
14	7	-0.001766	-0.001837	-0.001756	-0.001768	-0.001772	-0.001790
14	8	-0.001757	-0.001854	-0.001766	-0.001775	-0.001777	-0.001801

PORT NO.		43	44	45	46	47	48
RUN	PT.						
14	1	-0.001745	-0.001728	-0.001745	-0.001745	-0.000004	-0.000003
14	2	-0.001789	-0.001774	-0.001780	-0.001780	0.000000	0.000000
14	3	-0.001768	-0.001766	-0.001767	-0.001767	0.000001	0.000002
14	4	-0.001763	-0.001760	-0.001764	-0.001763	0.000000	0.000001
14	5	-0.001782	-0.001780	-0.001779	-0.001780	0.000000	0.000001
14	6	-0.001758	-0.001757	-0.001754	-0.001754	0.000001	0.000001
14	7	-0.001768	-0.001767	-0.001767	-0.001767	0.000001	0.000001
14	8	-0.001777	-0.001776	-0.001780	-0.001782	0.000000	0.000000

CHANNEL		0	1	2	3	4	RPM
RUN	PT						
14	1	0.003768	0.003589	0.003287	0.002579	0.003207	12075
14	2	0.003779	0.003580	0.003258	0.002556	0.003179	13120
14	3	0.003774	0.003583	0.003246	0.002572	0.003178	14109
14	4	0.003780	0.003582	0.003224	0.002556	0.003173	15023
14	5	0.003783	0.003587	0.003234	0.002582	0.003172	16078
14	6	0.003780	0.003587	0.003238	0.002608	0.003172	17074
14	7	0.003782	0.003589	0.003241	0.002638	0.003187	18917
14	8	0.003789	0.003598	0.003235	0.002655	0.003188	19987

CHANNEL		5	6	20	21	23	RPM
RUN	PT						
14	1	-0.000182	0.002011	-0.000984	0.000831	0.004171	12075
14	2	-0.000284	0.001853	-0.000764	0.001001	0.004103	13120
14	3	-0.000306	0.001803	-0.000565	0.001179	0.003926	14109
14	4	-0.000377	0.001847	-0.000460	0.001463	0.003750	15023
14	5	-0.000412	0.001854	-0.000206	0.001436	0.003632	16078
14	6	-0.000374	0.001986	-0.000052	0.001591	0.003421	17074
14	7	-0.000374	0.002123	0.000354	0.002022	0.003110	18917
14	8	-0.000312	0.002019	0.000631	0.002233	0.002984	19987

CHANNEL		23	24	25	26	27	RPM
RUN	PT						
14	1	0.004171	0.003515	0.003002	0.007604	0.002089	12075
14	2	0.004103	0.003501	0.002996	0.007649	0.002100	13120
14	3	0.003926	0.003457	0.002996	0.007651	0.002103	14109
14	4	0.003750	0.003409	0.002996	0.007636	0.002099	15023
14	5	0.003632	0.003358	0.002995	0.007658	0.002106	16078
14	6	0.003421	0.003271	0.002995	0.007620	0.002094	17074
14	7	0.003110	0.003159	0.002995	0.007639	0.002100	18917
14	8	0.002984	0.003100	0.002996	0.007644	0.002105	19987

TABLE XXII

TTR INPUT DATA

PORT NO. RUN PT.		1	2	3	4	5	6
15	1	0.000000	0.001361	0.006490	0.006281	0.004148	0.004103
15	2	-0.000002	0.001359	0.006486	0.000104	0.004135	0.004087
15	3	0.000000	0.001360	0.006480	0.000154	0.004125	0.004074
15	4	0.000000	0.001359	0.006482	0.000162	0.004119	0.004072
15	5	-0.000001	0.001359	0.006513	0.000182	0.004152	0.004101
15	6	0.000000	0.001359	0.006526	0.000198	0.004151	0.004107
15	7	0.000000	0.001361	0.006485	0.000206	0.004125	0.004069
15	8	0.000000	0.001360	0.006487	0.000212	0.004124	0.004071

PORT NO. RUN PT.		7	8	9	10	11	12
15	1	0.004106	0.004005	0.004105	0.004093	-0.001794	-0.002425
15	2	0.004091	0.003994	0.004092	0.004082	-0.001790	-0.002371
15	3	0.004080	0.003985	0.004082	0.004072	-0.001787	-0.002315
15	4	0.004078	0.003981	0.004078	0.004066	-0.001797	-0.002261
15	5	0.004106	0.004007	0.004104	0.004093	-0.001803	-0.002202
15	6	0.004112	0.004012	0.004109	0.004097	-0.001810	-0.002138
15	7	0.004075	0.003980	0.004076	0.004068	-0.001801	-0.001979
15	8	0.004076	0.003980	0.004073	0.004062	-0.001797	-0.001893

PORT NO. RUN PT.		13	14	15	16	17	18
15	1	-0.000489	-0.002051	-0.001785	-0.002353	-0.002487	0.001308
15	2	-0.000490	-0.002052	-0.001786	-0.002255	-0.002440	0.001307
15	3	-0.000492	-0.002053	-0.001786	-0.002128	-0.002395	0.001304
15	4	-0.000495	-0.002054	-0.001787	-0.001995	-0.002349	0.001302
15	5	-0.000482	-0.002047	-0.001780	-0.001833	-0.002302	0.001320
15	6	-0.000480	-0.002046	-0.001778	-0.001676	-0.002234	0.001323
15	7	-0.000491	-0.002053	-0.001780	-0.001413	-0.002109	0.001313
15	8	-0.000494	-0.002055	-0.001779	-0.001281	-0.002038	0.001314

PORT NO. RUN PT.		19	20	21	22	23	24
15	1	-0.000034	-0.002430	-0.002435	0.000115	-0.001682	-0.001724
15	2	-0.000037	-0.002425	-0.002378	0.000109	-0.001626	-0.001646
15	3	-0.000038	-0.002421	-0.002326	0.000109	-0.001560	-0.001573
15	4	-0.000042	-0.002417	-0.002266	0.000109	-0.001483	-0.001493
15	5	-0.000038	-0.002411	-0.002208	0.000120	-0.001380	-0.001385
15	6	-0.000042	-0.002399	-0.002138	0.000122	-0.001313	-0.001319
15	7	-0.000051	-0.002371	-0.001983	0.000111	-0.001185	-0.001095
15	8	-0.000054	-0.002350	-0.001893	0.000110	-0.001138	-0.001034

PORT NO. RUN PT.		25	26	27	28	29	30
15	1	-0.000001	0.001359	0.004124	-0.002433	-0.001803	-0.001585
15	2	0.000000	0.001360	0.004106	-0.002376	-0.001723	-0.001495
15	3	0.000000	0.001360	0.004097	-0.002322	-0.001637	-0.001422
15	4	0.000000	0.001360	0.004106	-0.002264	-0.001548	-0.001337
15	5	0.000000	0.001360	0.004112	-0.002202	-0.001446	-0.001216
15	6	0.000000	0.001360	0.004103	-0.002136	-0.001371	-0.001134
15	7	0.000000	0.001359	0.004079	-0.001978	-0.001201	-0.001035
15	8	0.000000	0.001360	0.004082	-0.001885	-0.001131	-0.000976

PORT NO.		31	32	33	34	35	36
RUN	PT.						
15	1	-0.001576	-0.001460	-0.001447	-0.001524	-0.001515	-0.001384
15	2	-0.001490	-0.001399	-0.001408	-0.001475	-0.001467	-0.001379
15	3	-0.001421	-0.001342	-0.001380	-0.001491	-0.001442	-0.001378
15	4	-0.001357	-0.001331	-0.001332	-0.001472	-0.001510	-0.001384
15	5	-0.001276	-0.001302	-0.001350	-0.001501	-0.001493	-0.001406
15	6	-0.001238	-0.001245	-0.001297	-0.001429	-0.001492	-0.001423
15	7	-0.001161	-0.001147	-0.001181	-0.001346	-0.001429	-0.001393
15	8	-0.001111	-0.001107	-0.001121	-0.001315	-0.001396	-0.001376

PORT NO.		37	38	39	40	41	42
RUN	PT.						
15	1	-0.001751	-0.001730	-0.001779	-0.001783	-0.001785	-0.001836
15	2	-0.001768	-0.001759	-0.001788	-0.001783	-0.001785	-0.001846
15	3	-0.001773	-0.001763	-0.001793	-0.001799	-0.001785	-0.001833
15	4	-0.001774	-0.001775	-0.001799	-0.001813	-0.001795	-0.001836
15	5	-0.001774	-0.001801	-0.001806	-0.001818	-0.001811	-0.001836
15	6	-0.001792	-0.001815	-0.001797	-0.001818	-0.001816	-0.001833
15	7	-0.001815	-0.001864	-0.001787	-0.001806	-0.001806	-0.001827
15	8	-0.001815	-0.001888	-0.001796	-0.001806	-0.001806	-0.001823

PORT NO.		43	44	45	46	47	48
RUN	PT.						
15	1	-0.001802	-0.001785	-0.001813	-0.001813	-0.000001	0.000000
15	2	-0.001817	-0.001797	-0.001809	-0.001809	0.000000	0.000000
15	3	-0.001818	-0.001802	-0.001803	-0.001804	-0.000001	0.000000
15	4	-0.001818	-0.001813	-0.001808	-0.001807	0.000000	0.000000
15	5	-0.001818	-0.001810	-0.001808	-0.001807	0.000000	0.000000
15	6	-0.001818	-0.001814	-0.001807	-0.001806	-0.000001	-0.000001
15	7	-0.001810	-0.001807	-0.001805	-0.001805	-0.000001	-0.000001
15	8	-0.001808	-0.001803	-0.001804	-0.001805	0.000000	0.000000

CHANNEL		0	1	2	3	4	RPM
RUN	PT						
15	1	0.006500	0.006012	0.005292	0.004331	0.005230	12081
15	2	0.006550	0.006080	0.005361	0.004401	0.005305	13081
15	3	0.006573	0.006113	0.005397	0.004459	0.005347	13982
15	4	0.006601	0.006138	0.005425	0.004510	0.005376	14981
15	5	0.006627	0.006179	0.005458	0.004597	0.005405	16089
15	6	0.006633	0.006186	0.005480	0.004639	0.005425	17025
15	7	0.006632	0.006196	0.005496	0.004664	0.005435	19047
15	8	0.006607	0.006183	0.005505	0.004686	0.005437	19940

CHANNEL		5	6	20	21	23	RPM
RUN	PT						
15	1	0.001189	0.003358	-0.001103	0.000655	0.004400	12081
15	2	0.001067	0.003418	-0.000980	0.000796	0.004238	13081
15	3	0.000931	0.003496	-0.000869	0.000932	0.004120	13982
15	4	0.000882	0.003484	-0.000750	0.001112	0.003957	14981
15	5	0.000825	0.003399	-0.000572	0.001292	0.003848	16089
15	6	0.000637	0.003619	-0.000402	0.001312	0.003723	17025
15	7	0.000639	0.003878	-0.000075	0.001753	0.003397	19047
15	8	0.000624	0.003893	0.000080	0.001983	0.003247	19940

CHANNEL		23	24	25	26	27	RPM
RUN	PT						
15	1	0.004400	0.003595	0.002995	0.007763	0.002104	12081
15	2	0.004238	0.003549	0.002994	0.007748	0.002218	13081
15	3	0.004120	0.003515	0.002995	0.007755	0.044709	13982
15	4	0.003957	0.003468	0.002995	0.007743	0.044690	14981
15	5	0.003848	0.003445	0.002995	0.007777	0.044705	16089
15	6	0.003723	0.003400	0.002994	0.007775	0.044691	17025
15	7	0.003397	0.003283	0.002995	0.007757	0.044668	19047
15	8	0.003247	0.003223	0.002994	0.007756	0.044663	19940

TABLE XXIII
RUN 10 REDUCED DATA

VELOCITY TRIANGLE

T.	V1	V2	VA1	VA2	VU1	VU2
1	1555.2	435.8	398.8	256.9	1503.2	-352.0
2	1540.5	406.8	397.7	257.1	1488.3	-315.2
3	1522.5	376.1	381.7	253.2	1473.9	-278.1
4	1501.2	337.0	382.5	254.9	1451.7	-220.4
5	1482.3	305.7	374.3	252.7	1434.3	-171.9
6	1457.8	285.2	364.1	251.4	1411.6	-134.6
7	1436.0	270.9	356.4	250.4	1391.1	-103.3
8	1394.9	255.2	311.4	252.0	1359.7	-40.2
9	1401.8	263.0	378.4	262.5	1349.8	-16.0

	MACH NUMBERS				ANGLES			
T.	M1	MA1	M2	MA2	A1	A2	B1	B2
1	1.521	0.390	0.357	0.210	75.1	-53.9	70.0	-71.4
2	1.501	0.388	0.333	0.210	75.0	-50.8	69.2	-71.4
3	1.475	0.370	0.307	0.207	75.5	-47.7	69.0	-71.7
4	1.447	0.369	0.275	0.208	75.2	-40.8	67.8	-71.1
5	1.423	0.359	0.249	0.206	75.4	-34.2	67.1	-70.9
6	1.390	0.347	0.232	0.205	75.5	-28.2	66.2	-71.0
7	1.362	0.338	0.220	0.204	75.6	-22.4	65.2	-71.1
8	1.309	0.292	0.208	0.205	77.1	-9.1	65.7	-70.8
9	1.318	0.356	0.214	0.214	74.3	-3.5	59.5	-70.3

LOSSES

T.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.0522	0.1048	0.4167	0.3315	0.4107	2.0E-02	-0.087
2	0.0643	0.1042	0.3751	0.3261	0.3730	1.6E-02	-0.061
3	0.0565	0.1047	0.3464	0.3217	0.3439	1.5E-02	-0.086
4	0.0785	0.1040	0.3211	0.3195	0.3227	1.0E-02	-0.037
5	0.0832	0.1038	0.2972	0.3156	0.2990	7.8E-03	-0.030
6	0.0898	0.1037	0.2622	0.3094	0.2603	5.4E-03	-0.020
7	0.0966	0.1034	0.2253	0.3024	0.2179	3.2E-03	-0.007
8	0.0462	0.1052	0.3379	0.3052	0.2973	4.1E-03	-0.170
9	0.1633	0.1008	0.0479	0.2739	0.0285	1.8E-03	0.190

RUN 10 REDUCED DATA

T.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.46	4.12	78.54	446.90	361.02	-121.87	5.90
2	3.50	4.08	83.39	435.93	358.74	-106.20	7.24
3	3.48	3.87	87.64	422.01	354.13	-90.88	8.62
4	3.52	3.84	90.08	403.29	349.41	-76.94	10.25
5	3.51	3.73	92.44	387.10	345.07	-63.33	12.40
6	3.51	3.58	94.85	372.60	339.71	-46.48	12.57
7	3.51	3.46	96.83	360.36	335.08	-29.20	13.49
8	3.51	2.96	98.35	337.17	327.34	-3.52	16.57
9	3.64	3.61	102.53	334.04	330.06	23.17	18.73

T.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	1.84697	59.622	636.4	17.235	17.253	14.471	12.094
2	1.85365	59.907	635.9	17.110	17.848	14.671	12.506
3	1.84776	59.570	636.0	17.124	18.523	15.404	12.983
4	1.85100	59.838	635.5	17.016	19.179	15.569	13.404
5	1.85015	59.790	634.6	17.023	19.800	16.036	13.904
6	1.85066	59.789	634.6	17.018	20.544	16.706	14.392
7	1.85237	59.763	634.2	17.011	21.204	17.266	14.936
8	1.85136	59.765	634.2	17.007	22.167	20.162	15.286
9	1.88051	60.717	634.4	16.697	22.734	16.806	16.903

T.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.289	0.243	0.203	13.614	2280990	119.57	0.655
2	0.298	0.245	0.209	11.585	2336330	130.72	0.687
3	0.311	0.259	0.218	9.785	2287810	136.93	0.728
4	0.321	0.260	0.224	8.525	2373860	140.52	0.741
5	0.331	0.268	0.233	7.434	2384580	142.20	0.763
6	0.344	0.279	0.241	6.544	2397370	145.35	0.783
7	0.355	0.289	0.250	5.871	2414040	148.90	0.799
8	0.371	0.337	0.256	5.018	2221090	146.46	0.806
9	0.374	0.277	0.278	4.678	2717720	151.29	0.801

T.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	1.993	1.227	35.584	1.02664	224.267	181.167	10000
2	2.002	1.226	37.618	1.02503	217.722	179.171	10889
3	1.991	1.226	39.752	1.02766	211.960	177.868	11820
4	2.000	1.225	40.693	1.02446	201.651	174.711	12718
5	1.998	1.223	41.824	1.02408	193.711	172.682	13608
6	1.998	1.223	42.916	1.02434	186.460	169.998	14506
7	1.997	1.223	43.843	1.02544	180.414	167.757	15316
8	1.997	1.223	44.529	1.02482	168.794	163.873	16626
9	2.029	1.223	45.688	1.02482	164.605	162.646	17493

T.	RTH	REFF	RAF	RPM
1	-0.11	-1.12	130.79	11077
2	-0.09	-0.95	132.31	12057
3	-0.07	-0.77	136.78	13089
4	-0.05	-0.68	138.09	14078
5	-0.03	-0.56	141.09	15051
6	-0.01	-0.39	145.51	16045
7	0.01	-0.23	149.26	16935
8	0.13	-0.00	168.25	18384
9	0.02	0.06	147.43	19346

NOZZLE PRESSURE RATIOS

T.	P1	P2	P3	P4	P5	P6	P7
1	0.204	0.441	0.251	0.283	0.213	0.197	0.661
2	0.210	0.441	0.251	0.283	0.223	0.202	0.661
3	0.219	0.441	0.251	0.283	0.243	0.209	0.661
4	0.225	0.441	0.251	0.283	0.262	0.215	0.661
5	0.232	0.441	0.251	0.283	0.284	0.221	0.662
6	0.241	0.441	0.251	0.283	0.313	0.229	0.662
7	0.251	0.441	0.251	0.283	0.322	0.237	0.662
8	0.256	0.441	0.251	0.284	0.331	0.243	0.663
9	0.277	0.441	0.251	0.284	0.349	0.255	0.663

T.	P8	P9
1	0.497	0.203
2	0.495	0.204
3	0.496	0.205
4	0.495	0.205
5	0.494	0.206
6	0.494	0.207
7	0.494	0.209
8	0.494	0.210
9	0.492	0.212

TABLE XXIV

RUN 11 REDUCED DATA

VELOCITY TRIANGLE

T.	V1	V2	VA1	VA2	VU1	VU2
1	1558.4	438.2	403.4	259.2	1505.3	-353.3
2	1543.7	405.1	410.5	258.8	1488.1	-311.7
3	1516.1	370.6	387.4	253.3	1465.8	-270.6
4	1500.6	343.7	382.9	254.2	1450.9	-231.3
5	1481.5	313.5	382.1	255.8	1431.4	-181.3
6	1460.7	295.1	369.9	252.2	1413.1	-153.3
7	1435.1	273.5	366.0	253.1	1387.7	-103.7
8	1407.3	258.5	341.8	253.0	1365.2	-53.2

	MACH NUMBERS				ANGLES			
T.	M1	MA1	M2	MA2	A1	A2	B1	B2
1	1.517	0.393	0.358	0.211	75.0	-53.7	69.8	-71.3
2	1.497	0.398	0.330	0.211	74.6	-50.3	68.5	-71.3
3	1.459	0.373	0.301	0.206	75.2	-46.9	68.6	-71.5
4	1.439	0.367	0.279	0.207	75.2	-42.3	67.8	-71.3
5	1.415	0.365	0.255	0.208	75.1	-35.3	66.6	-70.9
6	1.387	0.351	0.240	0.205	75.3	-31.3	66.1	-71.2
7	1.354	0.345	0.222	0.205	75.2	-22.3	64.6	-70.9
8	1.319	0.320	0.210	0.205	75.9	-11.9	64.2	-70.7

LOSSES

T.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.0583	0.1002	0.4112	0.3165	0.4060	1.9E-02	-0.063
2	0.0824	0.0993	0.3498	0.3095	0.3519	1.3E-02	-0.005
3	0.0746	0.0999	0.3313	0.3074	0.3316	1.3E-02	-0.028
4	0.0815	0.0996	0.3057	0.3038	0.3074	1.0E-02	-0.014
5	0.0983	0.0989	0.2762	0.3000	0.2800	6.5E-03	0.027
6	0.0987	0.0991	0.2408	0.2946	0.2413	5.1E-03	0.021
7	0.1159	0.0985	0.2063	0.2886	0.2034	2.1E-03	0.063
8	0.0994	0.0991	0.2480	0.2861	0.2242	1.5E-03	0.006

RUN 11 REDUCED DATA

T.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.47	4.14	98.62	558.49	450.97	-152.27	7.30
2	3.50	4.20	104.40	541.32	446.35	-134.82	8.83
3	3.44	3.89	107.81	517.78	436.01	-118.28	10.99
4	3.47	3.82	112.28	504.49	434.17	-98.79	12.73
5	3.51	3.78	115.51	485.32	429.99	-80.22	15.56
6	3.48	3.62	117.92	469.52	422.90	-65.45	17.34
7	3.49	3.53	119.70	447.39	415.82	-39.11	17.64
8	3.49	3.25	121.83	426.18	409.95	-8.25	20.10

PT.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	2.30389	74.610	641.0	21.512	21.543	18.001	15.091
2	2.30660	74.951	641.0	21.440	22.321	17.861	15.732
3	2.28750	74.151	640.6	21.578	23.258	19.055	16.363
4	2.30123	74.517	639.6	21.458	24.072	19.516	16.890
5	2.31013	74.890	639.1	21.339	24.853	19.819	17.463
6	2.30148	74.566	639.0	21.447	25.669	20.617	18.071
7	2.30438	74.611	638.6	21.397	26.644	21.128	18.896
8	2.30926	74.639	638.6	21.408	27.656	22.987	19.731

PT.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.289	0.241	0.202	13.625	2861040	121.63	0.653
2	0.298	0.238	0.210	11.511	2988360	129.66	0.685
3	0.314	0.257	0.221	9.763	2902260	136.83	0.721
4	0.323	0.262	0.227	8.597	2948990	139.92	0.742
5	0.332	0.265	0.233	7.572	3036640	141.09	0.755
6	0.344	0.276	0.242	6.760	3009450	142.42	0.778
7	0.357	0.283	0.253	5.976	3080720	148.05	0.786
8	0.371	0.308	0.264	5.240	2980230	146.30	0.798

PT.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	2.494	1.236	35.576	1.02707	223.965	180.848	10011
2	2.505	1.236	37.491	1.02358	216.092	178.180	10935
3	2.478	1.235	39.143	1.02576	208.923	175.930	11808
4	2.491	1.233	40.598	1.02602	202.561	174.326	12632
5	2.503	1.232	41.574	1.02445	193.894	171.786	13514
6	2.492	1.232	42.630	1.02499	188.396	169.692	14261
7	2.494	1.231	43.259	1.02536	179.410	166.748	15197
8	2.495	1.231	44.016	1.02712	170.838	164.332	16238

PT.	·RTH	REFF	RAF	RPM
1	-0.11	-1.10	163.11	11129
2	-0.11	-0.95	162.61	12155
3	-0.07	-0.77	169.62	13123
4	-0.05	-0.65	172.91	14027
5	-0.04	-0.54	175.21	15000
6	-0.02	-0.38	180.19	15829
7	0.00	-0.25	183.74	16862
8	0.06	-0.08	195.93	18017

NOZZLE PRESSURE RATIOS

PT.	P1	P2	P3	P4	P5	P6	P7
1	0.203	0.441	0.250	0.281	0.222	0.196	0.655
2	0.210	0.440	0.250	0.281	0.238	0.203	0.655
3	0.221	0.441	0.250	0.281	0.266	0.212	0.656
4	0.228	0.441	0.250	0.281	0.284	0.217	0.656
5	0.234	0.441	0.250	0.281	0.300	0.221	0.656
6	0.243	0.441	0.251	0.282	0.327	0.230	0.657
7	0.253	0.441	0.250	0.282	0.335	0.239	0.658
8	0.263	0.441	0.251	0.283	0.345	0.248	0.659

PT.	P8	P9
1	0.488	0.206
2	0.487	0.206
3	0.489	0.209
4	0.487	0.210
5	0.486	0.211
6	0.486	0.211
7	0.487	0.212
8	0.486	0.214

TABLE XXV

RUN 12 REDUCED DATA

VELOCITY TRIANGLE

PT.	V1	V2	VA1	VA2	VU1	VU2
1	1438.8	369.6	361.2	240.8	1392.8	-280.4
2	1402.5	308.4	347.4	238.0	1358.8	-196.1
3	1341.9	260.2	319.3	238.4	1303.3	-104.1
4	1306.9	244.6	298.1	239.7	1272.4	-48.8
5	1286.2	242.2	304.3	242.0	1249.7	9.6
6	1266.0	238.3	288.7	238.2	1232.6	5.8

PT.	MACH NUMBERS M1	MA1	M2	MA2	ANGLES A1	A2	B1	B2
1	1.464	0.368	0.318	0.207	75.5	-49.3	69.1	-71.8
2	1.415	0.350	0.265	0.204	75.7	-39.5	67.9	-71.4
3	1.332	0.317	0.223	0.204	76.2	-23.6	66.1	-71.1
4	1.286	0.293	0.210	0.205	76.8	-11.5	65.5	-70.5
5	1.260	0.298	0.208	0.207	76.3	2.3	63.2	-69.5
6	1.235	0.282	0.204	0.204	76.8	1.4	61.7	-71.2

LOSSES

PT.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.0672	0.0975	0.3403	0.3125	·0.3365	1.5E-02	-0.034
2	0.0787	0.0974	0.3061	0.3079	0.3032	1.0E-02	-0.018
3	0.0869	0.0972	0.2847	0.2988	0.2643	5.0E-03	-0.018
4	0.0766	0.0973	0.3427	0.2994	0.3060	3.7E-03	-0.064
5	0.1116	0.0966	0.3338	0.2934	0.2924	4.1E-04	0.029
6	0.0953	0.0971	0.2546	0.2728	0.1812	1.9E-05	-0.024

RUN 12 REDUCED DATA

PT.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.52	3.87	81.85	422.33	350.63	-73.19	8.77
2	3.50	3.65	85.83	391.52	341.46	-46.88	11.87
3	3.51	3.25	90.24	355.41	328.73	6.87	15.45
4	3.52	2.99	89.68	333.20	320.71	27.69	18.08
5	3.52	3.02	88.08	312.68	315.13	46.68	20.26
6	3.51	2.83	93.34	308.88	310.36	72.73	22.55

PT.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	1.93601	59.889	574.1	17.014	19.087	15.467	13.506
2	1.93250	59.688	572.5	17.033	20.298	16.333	14.437
3	1.93971	59.875	571.9	17.036	22.230	18.410	16.191
4	1.93832	59.891	571.5	17.012	23.022	20.051	16.622
5	1.93916	59.834	571.3	17.018	23.573	19.844	17.555
6	1.93629	59.730	570.9	17.025	24.296	21.073	18.356

PT.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.319	0.258	0.226	10.200	2632900	97.80	0.715
2	0.340	0.274	0.242	7.933	2665570	101.53	0.755
3	0.371	0.307	0.270	5.954	2673260	103.20	0.785
4	0.384	0.335	0.278	5.308	2612530	104.14	0.779
5	0.394	0.332	0.293	4.853	2734740	106.19	0.764
6	0.407	0.353	0.307	4.224	2656200	107.72	0.809

PT.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	2.002	1.107	38.866	1.01757	210.994	175.170	11610
2	1.995	1.104	40.954	1.01772	196.257	171.164	13152
3	2.001	1.103	42.946	1.01778	177.601	164.269	15240
4	2.002	1.102	42.683	1.01646	166.459	160.220	16161
5	2.000	1.101	41.970	1.01765	156.354	157.581	16918
6	1.996	1.101	44.568	1.01758	154.726	155.467	18154

PT.	RTH	REFF	RAF	RPM
1	-0.06	-0.73	137.06	12214
2	-0.02	-0.54	142.65	13817
3	0.06	-0.16	156.52	16003
4	0.12	-0.02	167.47	16964
5	0.12	0.02	166.30	17755
6	0.16	0.29	174.50	19046

NOZZLE PRESSURE RATIOS

PT.	P1	P2	P3	P4	P5	P6	P7
1	0.226	0.440	0.262	0.308	0.254	0.216	0.664
2	0.243	0.441	0.262	0.307	0.279	0.231	0.664
3	0.269	0.441	0.262	0.308	0.335	0.255	0.664
4	0.280	0.441	0.262	0.310	0.349	0.262	0.664
5	0.296	0.442	0.261	0.309	0.374	0.275	0.665
6	0.306	0.441	0.261	0.310	0.397	0.284	0.665

PT.	P8	P9
1	0.495	0.233
2	0.494	0.233
3	0.494	0.235
4	0.285	0.236
5	0.284	0.237
6	0.285	0.238

TABLE XXVI

RUN 13 REDUCED DATA

VELOCITY TRIANGLE

PT.	V1	V2	VA1	VA2	VU1	VU2
1	1426.6	357.6	375.7	241.1	1376.3	-264.1
2	1407.7	335.5	357.1	239.7	1361.6	-234.7
3	1390.9	304.3	347.4	240.0	1346.8	-187.0
4	1370.3	277.2	341.4	238.4	1327.1	-141.4
5	1324.9	260.2	322.5	238.6	1285.0	-103.9
6	1307.4	247.9	319.7	240.0	1267.7	-62.3
7	1250.5	242.6	307.3	242.6	1212.1	-3.9
8	1230.0	248.7	298.6	243.5	1193.2	50.7

	MACH NUMBERS				ANGLES			
PT.	M1	MA1	M2	MA2	A1	A2	B1	B2
1	1.446	0.381	0.307	0.207	74.7	-47.6	68.1	-71.3
2	1.422	0.361	0.288	0.206	75.3	-44.4	68.0	-71.6
3	1.398	0.349	0.261	0.206	75.5	-37.9	67.4	-71.3
4	1.369	0.341	0.238	0.204	75.6	-30.7	66.4	-71.1
5	1.308	0.318	0.223	0.204	75.9	-23.5	65.2	-71.2
6	1.284	0.314	0.212	0.205	75.8	-14.5	63.7	-70.9
7	1.210	0.298	0.207	0.207	75.8	-0.9	59.4	-71.1
8	1.185	0.288	0.213	0.208	76.0	11.8	57.2	-70.6

LOSSES

PT.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.0995	0.0955	0.3204	0.3124	0.3234	1.1E-02	0.029
2	0.0878	0.0973	0.3001	0.3081	0.2992	1.1E-02	0.004
3	0.0876	0.0971	0.2929	0.3059	0.2895	8.7E-03	-0.003
4	0.0969	0.0970	0.2646	0.3013	0.2598	5.8E-03	0.015
5	0.1073	0.0953	0.2533	0.2952	0.2330	3.2E-03	0.013
6	0.1199	0.0957	0.2281	0.2874	0.1981	8.4E-04	0.052
7	0.1536	0.0956	0.1707	0.2636	0.0970	2.0E-03	0.136
8	0.1563	0.0942	0.2030	0.2535	0.1043	7.1E-03	0.125

RUN 13 REDUCED DATA

PT.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.55	3.99	79.95	416.97	348.95	-69.55	10.30
2	3.51	3.75	84.17	405.51	345.09	-60.62	10.13
3	3.53	3.61	87.13	390.31	342.06	-40.45	12.26
4	3.52	3.50	88.76	373.07	336.63	-23.08	14.09
5	3.52	3.23	89.69	352.33	325.59	7.73	15.91
6	3.53	3.17	91.25	337.65	321.60	30.28	18.52
7	3.54	2.97	92.76	308.45	307.44	64.01	22.53
8	3.54	2.85	91.87	289.39	302.45	86.35	24.10

PT.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	1.94983	60.216	574.3	16.950	19.185	15.093	13.625
2	1.94901	60.001	572.8	17.118	19.841	15.986	14.014
3	1.95315	60.059	572.9	17.006	20.479	16.633	14.572
4	1.95062	59.909	573.1	17.013	21.251	17.105	15.196
5	1.94853	59.851	573.3	17.006	22.275	18.536	16.102
6	1.95096	59.952	573.4	16.967	22.987	18.892	16.967
7	1.95055	60.010	574.2	16.949	24.114	20.238	18.082
8	1.94933	60.034	574.5	16.959	24.792	21.030	18.827

PT.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.319	0.251	0.226	10.351	2802710	90.46	0.698
2	0.331	0.266	0.234	8.846	2733700	99.88	0.734
3	0.341	0.277	0.243	7.676	2725040	96.57	0.755
4	0.355	0.286	0.254	6.738	2747380	96.23	0.773
5	0.372	0.310	0.269	5.896	2752930	97.27	0.780
6	0.383	0.315	0.283	5.266	2794900	96.72	0.788
7	0.402	0.337	0.301	4.301	2876900	96.27	0.792
8	0.413	0.350	0.314	3.865	2861270	98.72	0.784

PT.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	2.013	1.107	37.755	1.01942	207.184	173.383	11485
2	2.005	1.104	39.941	1.02128	202.212	172.080	12449
3	2.007	1.104	41.305	1.02258	194.445	170.405	13388
4	2.002	1.105	42.172	1.02399	186.319	168.118	14265
5	2.000	1.105	42.649	1.02403	176.129	162.765	15261
6	2.004	1.105	43.312	1.02368	168.507	160.497	16200
7	2.006	1.107	43.955	1.02320	153.787	153.283	18014
8	2.006	1.107	43.509	1.02239	144.228	150.736	19013

PT.	RTH	REFF	RAF	RPM
1	-0.09	-0.81	135.30	12085
2	-0.04	-0.59	140.83	13081
3	-0.01	-0.47	145.11	14070
4	0.00	-0.35	148.23	14995
5	0.06	-0.11	157.74	16044
6	0.08	0.01	160.25	17032
7	0.13	0.32	169.54	18953
8	0.16	0.40	174.90	20009

NOZZLE PRESSURE RATIOS

PT.	P1	P2	P3	P4	P5	P6	P7
1	0.227	0.440	0.261	0.313	0.262	0.217	0.664
2	0.234	0.441	0.258	0.305	0.269	0.224	0.666
3	0.243	0.441	0.259	0.306	0.290	0.231	0.666
4	0.254	0.441	0.259	0.306	0.316	0.240	0.667
5	0.269	0.441	0.262	0.316	0.337	0.254	0.667
6	0.283	0.442	0.261	0.312	0.356	0.264	0.667
7	0.301	0.441	0.259	0.309	0.389	0.278	0.667
8	0.312	0.440	0.261	0.319	0.427	0.290	0.665

PT.	P8	P9
1	0.282	0.232
2	0.286	0.230
3	0.284	0.231
4	0.284	0.232
5	0.284	0.236
6	0.283	0.237
7	0.282	0.237
8	0.282	0.243

TABLE XXVII

RUN 14 REDUCED DATA

VELOCITY TRIANGLE

PT.	V1	V2	VA1	VA2	VU1	VU2
1	1480.7	358.8	387.2	244.5	1429.1	-262.6
2	1463.9	343.7	375.9	246.6	1414.8	-239.3
3	1440.4	307.8	350.8	244.7	1397.0	-186.7
4	1424.7	279.3	354.7	244.0	1379.8	-135.8
5	1398.7	268.5	349.7	245.6	1354.3	-108.4
6	1368.6	250.7	339.8	243.4	1325.8	-60.2
7	1317.0	249.0	320.3	248.2	1277.4	19.4
8	1291.5	253.1	318.1	248.8	1251.8	46.2

	MACH NUMBERS				ANGLES			
PT.	M1	MA1	M2	MA2	A1	A2	B1	B2
1	1.473	0.385	0.301	0.205	74.8	-47.0	68.6	-71.0
2	1.450	0.372	0.288	0.207	75.1	-44.1	68.1	-71.2
3	1.418	0.345	0.258	0.205	75.9	-37.3	68.3	-71.0
4	1.396	0.348	0.233	0.204	75.6	-29.1	66.9	-70.6
5	1.361	0.340	0.224	0.205	75.5	-23.8	65.5	-70.8
6	1.322	0.328	0.209	0.203	75.6	-13.9	64.2	-70.7
7	1.255	0.305	0.208	0.207	75.9	4.5	61.4	-70.0
8	1.223	0.301	0.211	0.208	75.7	10.5	58.6	-70.3

LOSSES

PT.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.0836	0.1011	0.3624	0.3219	0.3652	1.3E-02	-0.001
2	0.0836	0.1008	0.3245	0.3157	0.3264	1.1E-02	-0.007
3	0.0650	0.1017	0.3528	0.3176	0.3476	1.2E-02	-0.065
4	0.0874	0.1012	0.3121	0.3124	0.3112	7.3E-03	-0.011
5	0.1039	0.1003	0.2528	0.3024	0.2469	3.7E-03	0.026
6	0.1153	0.1004	0.2271	0.2959	0.2131	1.5E-03	0.051
7	0.1293	0.1001	0.2509	0.2835	0.2019	1.2E-04	0.075
8	0.1501	0.0989	0.1915	0.2661	0.1167	3.4E-03	0.139

RUN 14 REDUCED DATA

PT.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.45	4.04	79.91	417.10	351.50	-98.45	8.31
2	3.54	3.90	85.42	410.32	350.15	-76.41	10.01
3	3.52	3.59	87.89	392.62	345.68	-56.50	11.79
4	3.53	3.60	89.39	375.04	340.94	-45.96	14.63
5	3.56	3.50	92.64	363.15	335.83	-20.62	14.36
6	3.52	3.35	92.69	342.14	327.05	-5.20	15.91
7	3.54	3.07	93.35	311.03	315.91	35.42	20.22
8	3.55	3.01	94.63	298.40	310.03	63.05	22.33

PT.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	1.89142	59.668	603.1	17.284	18.409	14.757	13.040
2	1.90319	60.123	602.2	17.002	19.075	15.411	13.427
3	1.90295	60.009	602.2	17.053	19.855	16.732	14.001
4	1.90022	60.001	602.0	17.017	20.507	16.663	14.473
5	1.90703	60.203	602.0	16.896	21.276	17.198	15.146
6	1.89705	59.846	602.0	17.017	21.950	17.886	15.789
7	1.90177	59.999	602.5	16.970	23.276	19.531	17.073
8	1.90469	60.063	602.5	16.929	24.090	19.939	18.062

PT.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.309	0.247	0.219	10.741	2557360	117.52	0.694
2	0.317	0.256	0.223	9.250	2565440	120.25	0.725
3	0.331	0.279	0.233	7.969	2470460	121.01	0.749
4	0.342	0.278	0.241	7.034	2552350	123.40	0.762
5	0.353	0.286	0.252	6.202	2614610	124.63	0.780
6	0.367	0.299	0.264	5.464	2625440	123.26	0.789
7	0.388	0.326	0.285	4.514	2642310	123.76	0.782
8	0.401	0.332	0.301	4.060	2705890	121.56	0.788

PT.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	1.994	1.163	37.161	1.02273	209.150	176.255	11198
2	2.009	1.161	39.450	1.02051	204.193	174.249	12177
3	2.006	1.161	40.671	1.02228	195.755	172.354	13094
4	2.005	1.161	41.378	1.02081	187.016	170.015	13945
5	2.012	1.161	42.738	1.02100	180.479	166.903	14925
6	2.000	1.161	43.016	1.02172	171.053	163.509	15849
7	2.005	1.161	43.196	1.02208	155.104	157.536	17552
8	2.007	1.162	43.739	1.02258	148.644	154.440	18545

PT.	RTH	REFF	RAF	RPM
1	-0.11	-1.01	132.80	12075
2	-0.07	-0.74	137.14	13120
3	-0.02	-0.61	145.50	14109
4	-0.02	-0.53	145.19	15023
5	0.01	-0.30	148.96	16078
6	0.03	-0.15	153.39	17074
7	0.10	0.12	164.56	18917
8	0.12	0.28	167.50	19987

NOZZLE PRESSURE RATIOS

PT.	P1	P2	P3	P4	P5	P6	P7
1	0.219	0.439	0.248	0.290	0.263	0.210	0.661
2	0.224	0.439	0.248	0.291	0.272	0.214	0.661
3	0.233	0.439	0.248	0.291	0.289	0.222	0.661
4	0.243	0.439	0.248	0.290	0.312	0.228	0.661
5	0.253	0.439	0.248	0.292	0.325	0.239	0.661
6	0.263	0.439	0.248	0.291	0.341	0.248	0.662
7	0.283	0.440	0.248	0.292	0.368	0.264	0.662
8	0.301	0.440	0.248	0.296	0.411	0.280	0.663

PT.	P8	P9
1	0.498	0.216
2	0.496	0.217
3	0.495	0.217
4	0.494	0.216
5	0.489	0.219
6	0.496	0.220
7	0.492	0.222
8	0.483	0.228

TABLE XXVIII

RUN 15 REDUCED DATA

VELOCITY TRIANGLE

PT.	V1	V2	VA1	VA2	VU1	VU2
1	1587.6	428.9	431.6	265.7	1527.8	-336.7
2	1567.5	392.6	419.0	265.9	1510.4	-288.9
3	1552.5	366.4	409.3	264.6	1497.6	-253.5
4	1535.9	334.8	416.3	264.8	1478.4	-204.8
5	1519.0	313.8	391.7	264.3	1467.6	-169.1
6	1499.2	297.3	390.6	264.7	1447.5	-135.3
7	1446.5	269.7	363.7	265.4	1400.1	-47.9
8	1420.9	267.1	361.9	267.0	1374.1	-9.9

MACH NUMBERS / ANGLES

PT.	M1	MA1	M2	MA2	A1	A2	B1	B2
1	1.509	0.410	0.342	0.212	74.2	-51.7	68.3	-71.3
2	1.477	0.395	0.312	0.211	74.5	-47.4	67.9	-71.0
3	1.455	0.384	0.290	0.210	74.7	-43.8	67.5	-71.1
4	1.432	0.388	0.265	0.209	74.3	-37.7	65.9	-70.8
5	1.408	0.363	0.248	0.209	75.1	-32.6	66.0	-71.0
6	1.382	0.360	0.234	0.209	74.9	-27.1	64.7	-71.0
7	1.316	0.331	0.212	0.209	75.4	-10.2	62.7	-70.6
8	1.284	0.327	0.210	0.210	75.2	-2.1	60.7	-70.4

LOSSES

PT.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.0886	0.1051	0.3417	0.3273	0.3457	1.2E-02	0.001
2	0.0917	0.1051	0.3282	0.3268	0.3331	1.1E-02	0.003
3	0.0923	0.1052	0.3017	0.3234	0.3073	9.1E-03	-0.001
4	0.1161	0.1044	0.2360	0.3165	0.2507	4.7E-03	0.061
5	0.1001	0.1052	0.2454	0.3142	0.2488	4.9E-03	0.008
6	0.1162	0.1047	0.1890	0.3063	0.1920	2.2E-03	0.050
7	0.1212	0.1048	0.1884	0.2960	0.1631	1.5E-04	0.055
8	0.1414	0.1042	0.1555	0.2862	0.1164	4.8E-04	0.117

RUN 15 REDUCED DATA

PT.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.59	4.33	84.34	440.01	359.52	-110.33	6.55
2	3.57	4.14	87.97	423.85	354.90	-97.97	7.96
3	3.57	3.99	91.40	411.99	351.54	-86.85	9.32
4	3.58	4.02	94.05	395.66	346.84	-75.02	11.12
5	3.60	3.75	98.24	384.81	344.48	-57.21	12.92
6	3.62	3.70	100.57	372.29	340.00	-40.21	13.12
7	3.59	3.34	102.66	339.69	328.28	-7.50	17.53
8	3.58	3.28	102.72	324.66	322.30	8.00	19.83

PT.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	1.80965	60.115	670.5	16.751	17.233	13.875	12.037
2	1.80692	60.027	673.0	16.794	17.824	14.508	12.469
3	1.80513	59.932	674.3	16.802	18.367	15.006	12.837
4	1.80417	59.909	675.3	16.730	18.980	14.909	13.281
5	1.80507	60.119	676.3	16.694	19.659	16.026	13.715
6	1.80638	60.146	676.9	16.632	20.337	16.268	14.219
7	1.80318	59.899	677.2	16.703	21.662	17.912	15.364
8	1.80378	59.878	677.3	16.722	22.264	18.230	16.016

PT.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.287	0.231	0.200	12.200	2301800	136.46	0.673
2	0.297	0.242	0.208	10.466	2290550	143.17	0.699
3	0.306	0.250	0.214	9.176	2276710	149.29	0.726
4	0.317	0.249	0.222	8.026	2364690	151.96	0.745
5	0.327	0.267	0.228	7.014	2280710	154.90	0.771
6	0.338	0.270	0.236	6.293	2332180	162.16	0.785
7	0.362	0.299	0.256	5.045	2306400	162.42	0.800
8	0.372	0.304	0.267	4.618	2363560	163.01	0.798

PT.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	2.009	1.293	36.921	1.02403	218.998	178.939	10625
2	2.006	1.297	38.494	1.02587	211.263	176.895	11484
3	2.003	1.300	40.019	1.02753	205.680	175.498	12263
4	2.002	1.302	41.166	1.02811	197.603	173.222	13130
5	2.009	1.304	42.818	1.02575	191.513	171.443	14091
6	2.010	1.305	43.793	1.02652	185.196	169.133	14903
7	2.002	1.306	44.876	1.02918	169.676	163.977	16669
8	2.001	1.306	44.916	1.02994	162.227	161.047	17450

PT.	RTH	REFF	RAF	RPM
1	-0.13	-1.00	127.73	12081
2	-0.10	-0.87	131.71	13081
3	-0.08	-0.73	134.85	13982
4	-0.08	-0.62	134.51	14981
5	-0.03	-0.43	141.47	16089
6	-0.01	-0.29	143.23	17025
7	0.05	-0.01	153.94	19047
8	0.07	0.11	156.22	19940

NOZZLE PRESSURE RATIOS

PT.	P1	P2	P3	P4	P5	P6	P7
1	0.201	0.438	0.247	0.280	0.210	0.194	0.658
2	0.209	0.439	0.248	0.280	0.223	0.200	0.659
3	0.216	0.439	0.248	0.280	0.238	0.206	0.660
4	0.222	0.439	0.248	0.280	0.255	0.211	0.660
5	0.229	0.439	0.248	0.280	0.274	0.217	0.660
6	0.236	0.439	0.248	0.280	0.293	0.225	0.660
7	0.257	0.440	0.248	0.281	0.326	0.241	0.661
8	0.267	0.439	0.248	0.281	0.343	0.250	0.661

PT.	P8	P9
1	0.494	0.201
2	0.495	0.202
3	0.495	0.203
4	0.495	0.203
5	0.494	0.203
6	0.493	0.204
7	0.494	0.209
8	0.493	0.211

TABLE XXIX
RUN 12 REDUCED DATA

VELOCITY TRIANGLE

PT.	V1	V2	VA1	VA2	VU1	VU2
1	1436.1	369.5	363.2	241.5	1389.4	-279.7
2	1400.0	308.6	349.1	238.7	1355.8	-195.7
3	1339.4	260.7	320.7	239.1	1300.5	-103.9
4	1303.0	245.6	300.1	240.8	1268.0	-48.6
5	1283.8	242.9	305.6	242.8	1246.9	9.6
6	1263.5	239.0	290.0	238.9	1229.7	5.8

	MACH NUMBERS				ANGLES			
PT.	M1	MA1	M2	MA2	A1	A2	B1	B2
1	1.460	0.369	0.318	0.208	75.4	-49.2	68.9	-71.8
2	1.411	0.352	0.265	0.205	75.6	-39.3	67.7	-71.4
3	1.329	0.318	0.223	0.205	76.1	-23.5	65.9	-71.1
4	1.281	0.295	0.211	0.206	76.7	-11.4	65.2	-70.4
5	1.257	0.299	0.208	0.208	76.2	2.3	63.0	-69.5
6	1.231	0.283	0.205	0.205	76.7	1.4	61.5	-71.2

LOSSES

PT.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.0715	0.0973	0.3357	0.3122	0.3327	1.5E-02	-0.025
2	0.0828	0.0972	0.3014	0.3076	0.2991	9.9E-03	-0.009
3	0.0907	0.0970	0.2807	0.2983	0.2605	4.6E-03	-0.009
4	0.0829	0.0971	0.3375	0.2985	0.3008	3.1E-03	-0.049
5	0.1156	0.0965	0.3300	0.2926	0.2884	2.8E-04	0.039
6	0.0995	0.0970	0.2511	0.2720	0.1771	7.2E-05	-0.014

RUN 12 REDUCED DATA

PT.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.52	3.88	81.85	422.33	350.63	-73.19	8.77
2	3.50	3.66	85.83	391.52	341.46	-46.88	11.87
3	3.51	3.26	90.24	355.41	328.73	6.87	15.45
4	3.52	2.99	89.68	333.20	320.71	27.69	18.08
5	3.52	3.02	88.08	312.68	315.13	46.68	20.26
6	3.51	2.84	93.34	308.88	310.36	72.73	22.55

PT.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	1.93601	59.889	574.1	17.014	19.087	15.444	13.506
2	1.93250	59.688	572.5	17.033	20.298	16.313	14.437
3	1.93971	59.875	571.9	17.036	22.230	18.393	16.191
4	1.93832	59.891	571.5	17.012	23.022	20.027	16.622
5	1.93916	59.834	571.3	17.018	23.573	19.827	17.555
6	1.93629	59.730	570.9	17.025	24.296	21.057	18.356

PT.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.319	0.258	0.226	10.200	2657970	97.80	0.713
2	0.340	0.273	0.242	7.933	2688230	101.53	0.753
3	0.371	0.307	0.270	5.954	2693510	103.20	0.783
4	0.384	0.334	0.278	5.308	2642670	104.14	0.777
5	0.394	0.331	0.293	4.853	2755010	106.19	0.762
6	0.407	0.353	0.307	4.224	2675940	107.72	0.808

PT.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	2.002	1.107	38.866	1.02000	210.994	175.170	11610
2	1.995	1.104	40.954	1.02000	196.257	171.164	13152
3	2.001	1.103	42.946	1.02000	177.601	164.269	15240
4	2.002	1.102	42.683	1.02000	166.459	160.220	16161
5	2.000	1.101	41.970	1.02000	156.354	157.581	16918
6	1.996	1.101	44.568	1.02000	154.726	155.467	18154

PT.	RTH	REFF	RAF	RPM
1	-0.06	-0.73	137.06	12214
2	-0.03	-0.53	142.65	13817
3	0.06	-0.15	156.52	16003
4	0.12	-0.01	167.47	16964
5	0.11	0.03	166.30	17755
6	0.16	0.30	174.50	19046

NOZZLE PRESSURE RATIOS

PT.	P1	P2	P3	P4	P5	P6	P7
1	0.226	0.440	0.262	0.308	0.254	0.216	0.664
2	0.243	0.441	0.262	0.307	0.279	0.231	0.664
3	0.269	0.441	0.262	0.308	0.335	0.255	0.664
4	0.280	0.441	0.262	0.310	0.349	0.262	0.664
5	0.296	0.442	0.261	0.309	0.374	0.275	0.665
6	0.306	0.441	0.261	0.310	0.397	0.284	0.665

PT.	P8	P9
1	0.495	0.233
2	0.494	0.233
3	0.494	0.235
4	0.285	0.236
5	0.284	0.237
6	0.285	0.238

TABLE XXX

RUN 13 REDUCED DATA

VELOCITY TRIANGLE

PT.	V1	V2	VA1	VA2	VU1	VU2
1	1426.0	357.6	376.2	241.3	1375.5	-264.0
2	1409.1	335.4	356.1	239.3	1363.3	-235.0
3	1393.7	304.0	345.5	239.2	1350.2	-187.5
4	1374.7	276.5	338.6	237.2	1332.3	-142.0
5	1329.2	259.3	320.0	237.4	1290.1	-104.3
6	1311.2	246.9	317.5	238.9	1272.2	-62.5
7	1253.7	241.7	305.6	241.6	1215.9	-3.9
8	1232.4	248.0	297.3	242.8	1196.0	50.8

	MACH NUMBERS				ANGLES			
PT.	M1	MA1	M2	MA2	A1	A2	B1	B2
1	1.445	0.381	0.307	0.207	74.7	-47.6	68.1	-71.3
2	1.424	0.360	0.288	0.206	75.4	-44.5	68.1	-71.6
3	1.402	0.347	0.261	0.205	75.6	-38.1	67.6	-71.4
4	1.375	0.339	0.237	0.203	75.7	-30.9	66.7	-71.2
5	1.313	0.316	0.222	0.203	76.1	-23.7	65.6	-71.3
6	1.289	0.312	0.211	0.204	76.0	-14.7	64.0	-71.0
7	1.215	0.296	0.207	0.207	75.9	-0.9	59.7	-71.1
8	1.188	0.287	0.212	0.208	76.0	11.8	57.4	-70.6

LOSSES

PT.	ZS	ZSTH	ZR	ZRTH	ZR*	ZI	Y
1	0.1005	0.0955	0.3192	0.3123	0.3223	1.1E-02	0.031
2	0.0856	0.0974	0.3028	0.3083	0.3014	1.1E-02	-0.001
3	0.0831	0.0973	0.2982	0.3064	0.2942	9.4E-03	-0.013
4	0.0899	0.0973	0.2731	0.3021	0.2675	6.6E-03	-0.001
5	0.1004	0.0956	0.2610	0.2961	0.2403	3.9E-03	-0.004
6	0.1137	0.0959	0.2353	0.2884	0.2053	1.2E-03	0.036
7	0.1485	0.0958	0.1763	0.2648	0.1034	1.5E-03	0.121
8	0.1524	0.0943	0.2068	0.2546	0.1089	6.3E-03	0.115

RUN 13 REDUCED DATA

PT.	P.R.	STPR	H.P.	RTM	STM	AXF	CLF
1	3.55	3.99	79.95	416.97	348.95	-69.55	10.30
2	3.51	3.75	84.17	405.51	345.09	-60.62	10.13
3	3.53	3.61	87.13	390.31	342.06	-40.45	12.26
4	3.52	3.50	88.76	373.07	336.63	-23.08	14.09
5	3.52	3.22	89.69	352.33	325.59	7.73	15.91
6	3.53	3.17	91.25	337.65	321.60	30.28	18.52
7	3.54	2.96	92.76	308.45	307.44	64.01	22.53
8	3.54	2.85	91.87	289.39	302.45	86.35	24.10

PT.	MW-DOT	PTO	TTO	PHD	P-TIP	P1	P-HUB
1	1.94983	60.216	574.3	16.950	19.185	15.087	13.625
2	1.94901	60.001	572.8	17.118	19.841	15.998	14.014
3	1.95315	60.059	572.9	17.006	20.479	16.655	14.572
4	1.95062	59.909	573.1	17.013	21.251	17.138	15.196
5	1.94853	59.851	573.3	17.006	22.275	18.567	16.102
6	1.95096	59.952	573.4	16.967	22.987	18.920	16.967
7	1.95055	60.010	574.2	16.949	24.114	20.261	18.082
8	1.94933	60.034	574.5	16.959	24.792	21.046	18.827

PT.	PTIP/PTO	P1/PTO	PHUB/PTO	KIS	TURB RE	DEL T	ETA
1	0.319	0.251	0.226	10.351	2808940	90.46	0.698
2	0.331	0.267	0.234	8.846	2720590	99.88	0.735
3	0.341	0.277	0.243	7.676	2699390	96.57	0.757
4	0.355	0.286	0.254	6.738	2708710	96.23	0.776
5	0.372	0.310	0.269	5.896	2716240	97.27	0.783
6	0.383	0.316	0.283	5.266	2761740	96.72	0.790
7	0.402	0.338	0.301	4.301	2849530	96.27	0.794
8	0.413	0.351	0.314	3.865	2841450	98.72	0.785

PT.	DELTA	THETA	RHP	RMW-DOT	RRTM	RSTM	RN
1	2.013	1.107	37.755	1.02000	207.184	173.383	11485
2	2.005	1.104	39.941	1.02000	202.212	172.080	12449
3	2.007	1.104	41.305	1.02000	194.445	170.405	13388
4	2.002	1.105	42.172	1.02000	186.319	168.118	14265
5	2.000	1.105	42.649	1.02000	176.129	162.765	15261
6	2.004	1.105	43.312	1.02000	168.507	160.497	16200
7	2.006	1.107	43.955	1.02000	153.787	153.283	18014
8	2.006	1.107	43.509	1.02000	144.228	150.736	19013

PT.	RTH	REFF	RAF	RPM
1	-0.09	-0.80	135.30	12085
2	-0.04	-0.59	140.83	13081
3	-0.01	-0.48	145.11	14070
4	0.00	-0.36	148.23	14995
5	0.06	-0.12	157.74	16044
6	0.08	0.01	160.25	17032
7	0.13	0.31	169.54	18953
8	0.16	0.40	174.90	20009

NOZZLE PRESSURE RATIOS

PT.	P1	P2	P3	P4	P5	P6	P7
1	0.227	0.440	0.261	0.313	0.262	0.217	0.664
2	0.234	0.441	0.258	0.305	0.269	0.224	0.666
3	0.243	0.441	0.259	0.306	0.290	0.231	0.666
4	0.254	0.441	0.259	0.306	0.316	0.240	0.667
5	0.269	0.441	0.262	0.316	0.337	0.254	0.667
6	0.283	0.442	0.261	0.312	0.356	0.264	0.667
7	0.301	0.441	0.259	0.309	0.389	0.278	0.667
8	0.312	0.440	0.261	0.319	0.427	0.290	0.665

PT.	P8	P9
1	0.282	0.232
2	0.286	0.230
3	0.284	0.231
4	0.284	0.232
5	0.284	0.236
6	0.283	0.237
7	0.282	0.237
8	0.282	0.243

TABLE XXXI

PARAMETER CONVERGENCE INVESTIGATION

SCANS	AX FORCE	CL FORCE	DYNA Q	STATOR Q	RPM
10	-124.39	9.125	397.28	347.45	11418
20	-123.67	9.218	393.22	347.17	11508
30	-124.18	9.172	392.82	347.18	11471
40	-124.55	9.165	393.19	347.24	11485
50	-124.74	9.157	392.77	347.29	11453
60	-124.60	9.167	392.06	347.26	11461
70	-124.50	9.172	391.66	347.21	11465
80	-124.29	9.188	391.31	347.14	11487
90	-124.07	9.186	391.17	347.10	11500
100	-124.30	9.172	391.45	347.14	11487

TABLE XXXII

RUN 10 UNCERTAINTY DATA

PT.	RAF	+/-	% ERROR	P1/PTO	+/-	% ERROR
1	130.79	1.997	1.527	0.2427	0.0173	1.100
2	132.31	1.997	1.509	0.2449	0.0185	1.082
3	136.78	1.997	1.460	0.2586	0.0194	1.015
4	138.09	1.997	1.446	0.2602	0.0213	1.003
5	141.09	1.997	1.415	0.2682	0.0229	0.966
6	145.51	1.997	1.372	0.2794	0.0242	0.919
7	149.26	1.997	1.338	0.2889	0.0254	0.883
8	168.25	1.997	1.187	0.3374	0.0221	0.734
9	147.43	1.997	1.354	0.2768	0.0312	0.920

PT.	Z1	+/-	% ERROR	Z3	+/-	% ERROR
1	0.0522	0.0310	59.33	0.4167	0.0415	9.96
2	0.0643	0.0309	48.03	0.3751	0.0473	12.60
3	0.0565	0.0303	53.66	0.3464	0.0492	14.19
4	0.0785	0.0304	38.74	0.3211	0.0557	17.33
5	0.0832	0.0302	36.28	0.2972	0.0599	20.15
6	0.0898	0.0299	33.29	0.2622	0.0638	24.35
7	0.0966	0.0298	30.79	0.2253	0.0682	30.28
8	0.0462	0.0284	61.45	0.3379	0.0434	12.85
9	0.1633	0.0306	18.72	0.0479	0.1073	223.91

TABLE XXXIII

RUN 11 UNCERTAINTY DATA

PT.	RAF	+/-	% ERROR	P1/PTO	+/-	% ERROR
1	163.11	1.997	1.224	0.2413	0.0139	0.886
2	162.61	1.997	1.228	0.2383	0.0157	0.898
3	169.62	1.997	1.177	0.2570	0.0165	0.823
4	172.91	1.997	1.155	0.2619	0.0173	0.799
5	175.21	1.997	1.140	0.2646	0.0187	0.786
6	180.19	1.997	1.108	0.2765	0.0196	0.747
7	183.74	1.997	1.087	0.2832	0.0212	0.726
8	195.93	1.997	1.019	0.3080	0.0205	0.655

PT.	Z1	+/-	% ERROR	Z3	+/-	% ERROR
1	0.0583	0.0249	42.71	0.4112	0.0340	8.28
2	0.0824	0.0252	30.64	0.3498	0.0427	12.22
3	0.0746	0.0246	33.00	0.3313	0.0429	12.95
4	0.0815	0.0244	29.97	0.3057	0.0458	15.00
5	0.0983	0.0244	24.84	0.2762	0.0511	18.49
6	0.0987	0.0242	24.49	0.2408	0.0539	22.39
7	0.1159	0.0242	20.86	0.2063	0.0596	28.88
8	0.0994	0.0235	23.66	0.2480	0.0500	20.17

TABLE XXXIV

RUN 12 UNCERTAINTY DATA

PT.	RAF	+/-	% ERROR	P1/PTO	+/-	% ERROR
1	137.06	1.997	1.457	0.2583	0.0192	1.009
2	142.65	1.997	1.400	0.2736	0.0217	0.942
3	156.52	1.997	1.276	0.3075	0.0232	0.816
4	167.47	1.997	1.192	0.3348	0.0226	0.738
5	166.30	1.997	1.201	0.3316	0.0250	0.748
6	174.50	1.997	1.144	0.3528	0.0245	0.698

PT.	Z1	+/-	% ERROR	Z3	+/-	% ERROR
1	0.0672	0.0303	45.02	0.3403	0.0490	14.41
2	0.0787	0.0299	38.03	0.3061	0.0551	18.01
3	0.0869	0.0291	33.53	0.2847	0.0540	18.98
4	0.0766	0.0287	37.42	0.3427	0.0443	12.92
5	0.1116	0.0291	26.07	0.3338	0.0501	15.02
6	0.0953	0.0288	30.25	0.2546	0.0518	20.35

TABLE XXXV

RUN 13 UNCERTAINTY DATA

PT.	RAF	+/-	% ERROR	P1/PTO	+/-	% ERROR
1	135.30	1.997	1.476	0.2506	0.0211	1.046
2	140.83	1.997	1.418	0.2664	0.0213	0.971
3	145.11	1.997	1.376	0.2769	0.0221	0.924
4	148.23	1.997	1.347	0.2855	0.0239	0.893
5	157.74	1.997	1.266	0.3097	0.0245	0.811
6	160.25	1.997	1.246	0.3151	0.0257	0.794
7	169.54	1.997	1.178	0.3372	0.0272	0.733
8	174.90	1.997	1.142	0.3503	0.0273	0.702

PT.	Z1	+/-	% ERROR	Z3	+/-	% ERROR
1	0.0995	0.0310	31.13	0.3204	0.0572	17.85
2	0.0878	0.0302	34.39	0.3001	0.0558	18.60
3	0.0876	0.0298	34.04	0.2929	0.0564	19.27
4	0.0969	0.0298	30.73	0.2646	0.0616	23.28
5	0.1073	0.0294	27.37	0.2533	0.0591	23.32
6	0.1199	0.0294	24.50	0.2281	0.0631	27.64
7	0.1536	0.0294	19.16	0.1707	0.0670	39.23
8	0.1563	0.0294	18.78	0.2030	0.0622	30.64

TABLE XXXVI

RUN 14 UNCERTAINTY DATA

PT.	RAF	+/-	% ERROR	P1/PT0	+/-	% ERROR
1	132.80	1.997	1.504	0.2479	0.0209	1.074
2	137.14	1.997	1.456	0.2569	0.0211	1.017
3	145.50	1.997	1.372	0.2794	0.0210	0.916
4	145.19	1.997	1.375	0.2783	0.0235	0.922
5	148.96	1.997	1.340	0.2863	0.0249	0.888
6	153.39	1.997	1.302	0.2995	0.0269	0.846
7	164.56	1.997	1.213	0.3262	0.0271	0.763
8	167.50	1.997	1.192	0.3327	0.0285	0.746

PT.	Z1	+/-	% ERROR	Z3	+/-	% ERROR
1	0.0824	0.0312	37.91	0.3624	0.0538	14.84
2	0.0823	0.0305	37.09	0.3245	0.0554	7.07
3	0.0637	0.0295	46.33	0.3528	0.0486	13.76
4	0.0860	0.0298	34.70	0.3121	0.0581	18.62
5	0.1026	0.0297	29.00	0.2528	0.0650	25.70
6	0.1140	0.0297	26.08	0.2271	0.0695	30.60
7	0.1279	0.0294	22.96	0.2509	0.0622	24.78
8	0.1487	0.0295	19.83	0.1915	0.0693	36.18

TABLE XXXVII

RUN 15 UNCERTAINTY DATA

PT.	RAF	+/-	% ERROR	P1/PT0	+/-	% ERROR
1	127.73	1.997	1.563	0.2308	0.0196	1.170
2	131.71	1.997	1.516	0.2417	0.0207	1.102
3	134.85	1.997	1.481	0.2504	0.0217	1.054
4	134.51	1.997	1.484	0.2489	0.0247	1.065
5	141.47	1.997	1.411	0.2666	0.0239	0.970
6	143.23	1.997	1.394	0.2705	0.0258	0.953
7	153.94	1.997	1.297	0.2990	0.0269	0.847
8	156.22	1.997	1.278	0.3045	0.0286	0.830

PT.	Z1	+/-	% ERROR	Z3	+/-	% ERROR
1	0.0886	0.0321	36.23	0.3417	0.0560	16.39
2	0.0917	0.0315	34.37	0.3282	0.0574	17.49
3	0.0923	0.0311	33.68	0.3017	0.0604	20.03
4	0.1161	0.0316	27.21	0.2360	0.0759	32.15
5	0.1001	0.0304	30.33	0.2454	0.0675	27.52
6	0.1162	0.0304	26.20	0.1890	0.0774	40.93
7	0.1212	0.0298	24.56	0.1884	0.0730	38.75
8	0.1414	0.0299	21.16	0.1555	0.0793	50.99

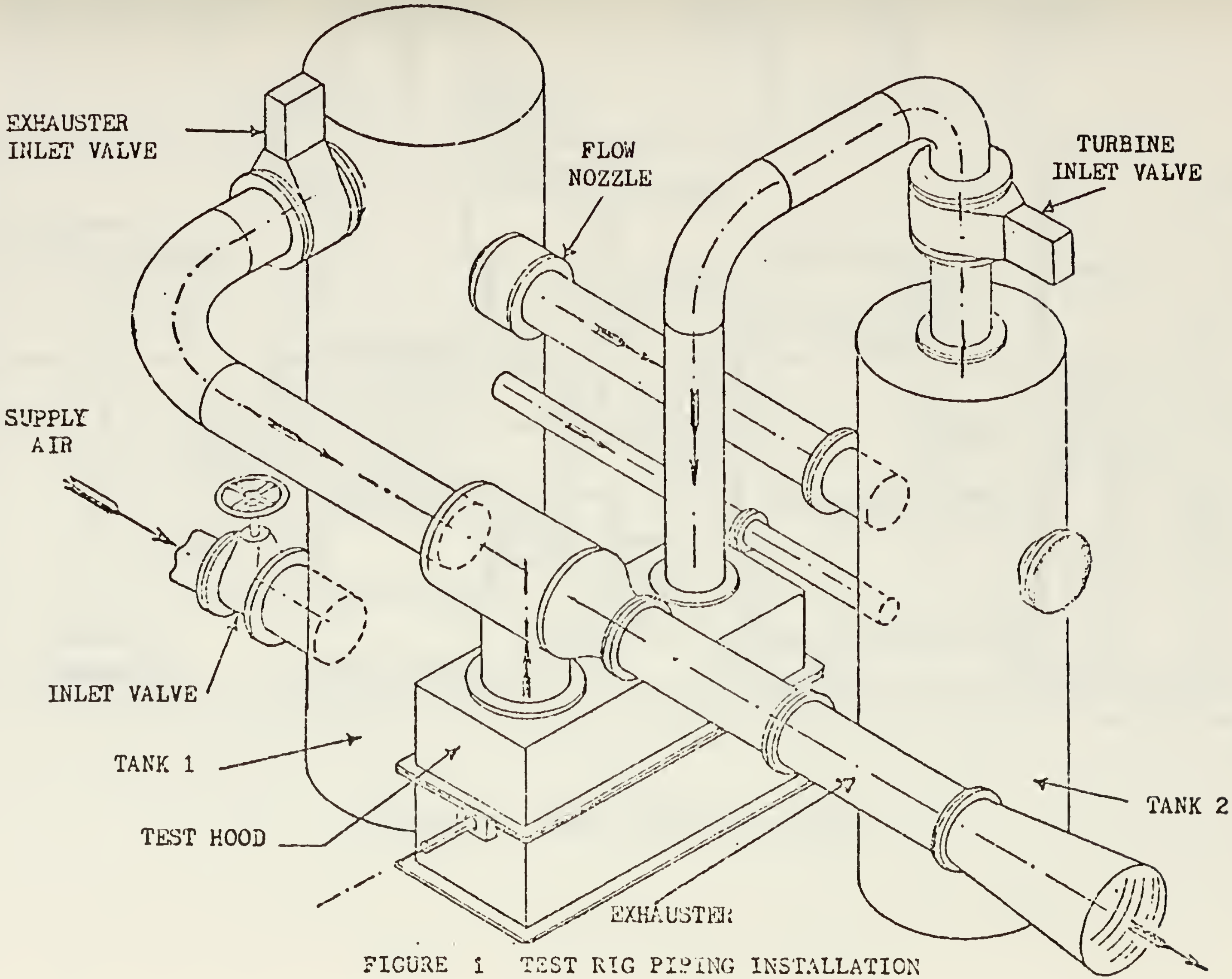


FIGURE 1 TEST RIG PIPING INSTALLATION

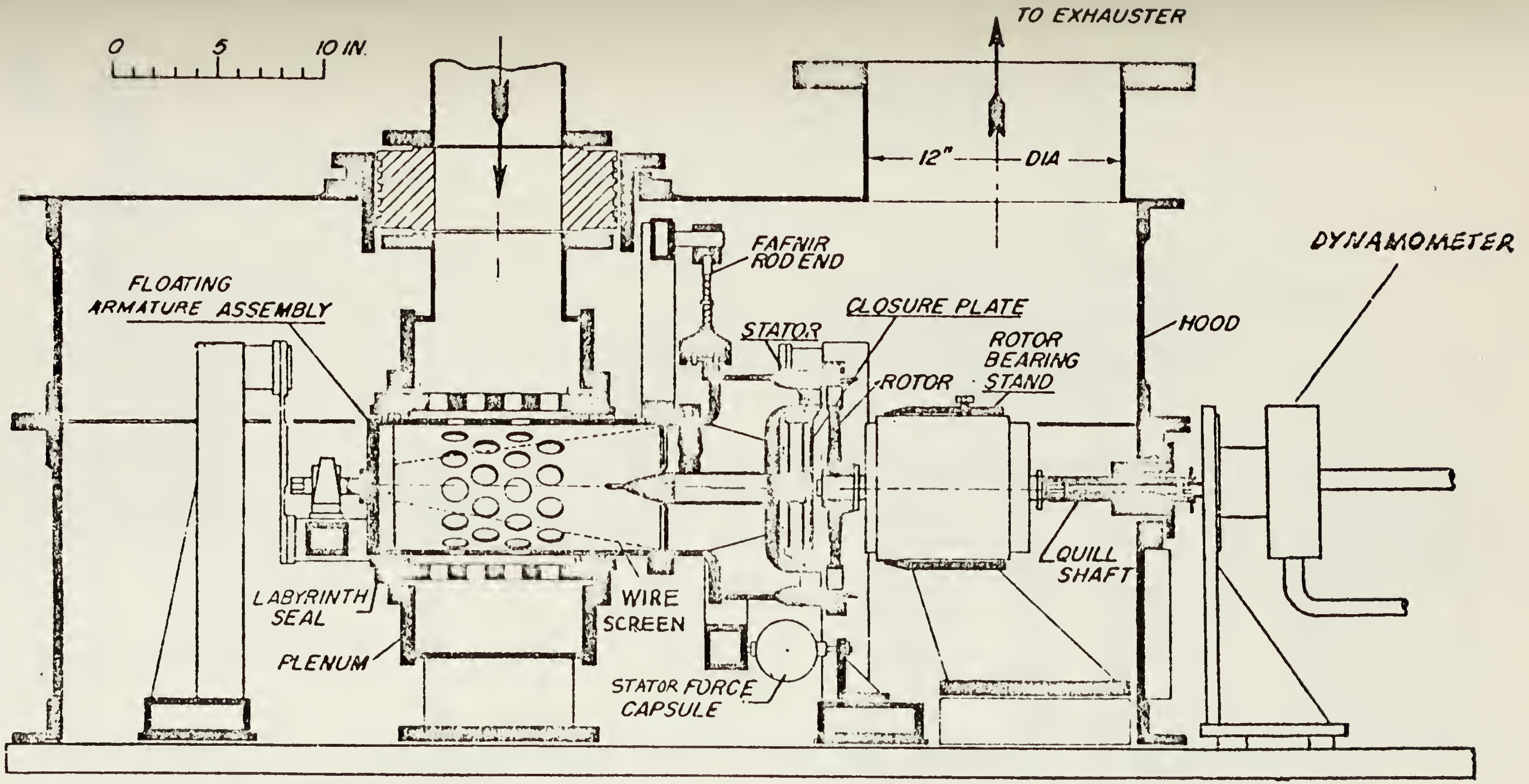


FIGURE 2 THE TURBINE TEST RIG

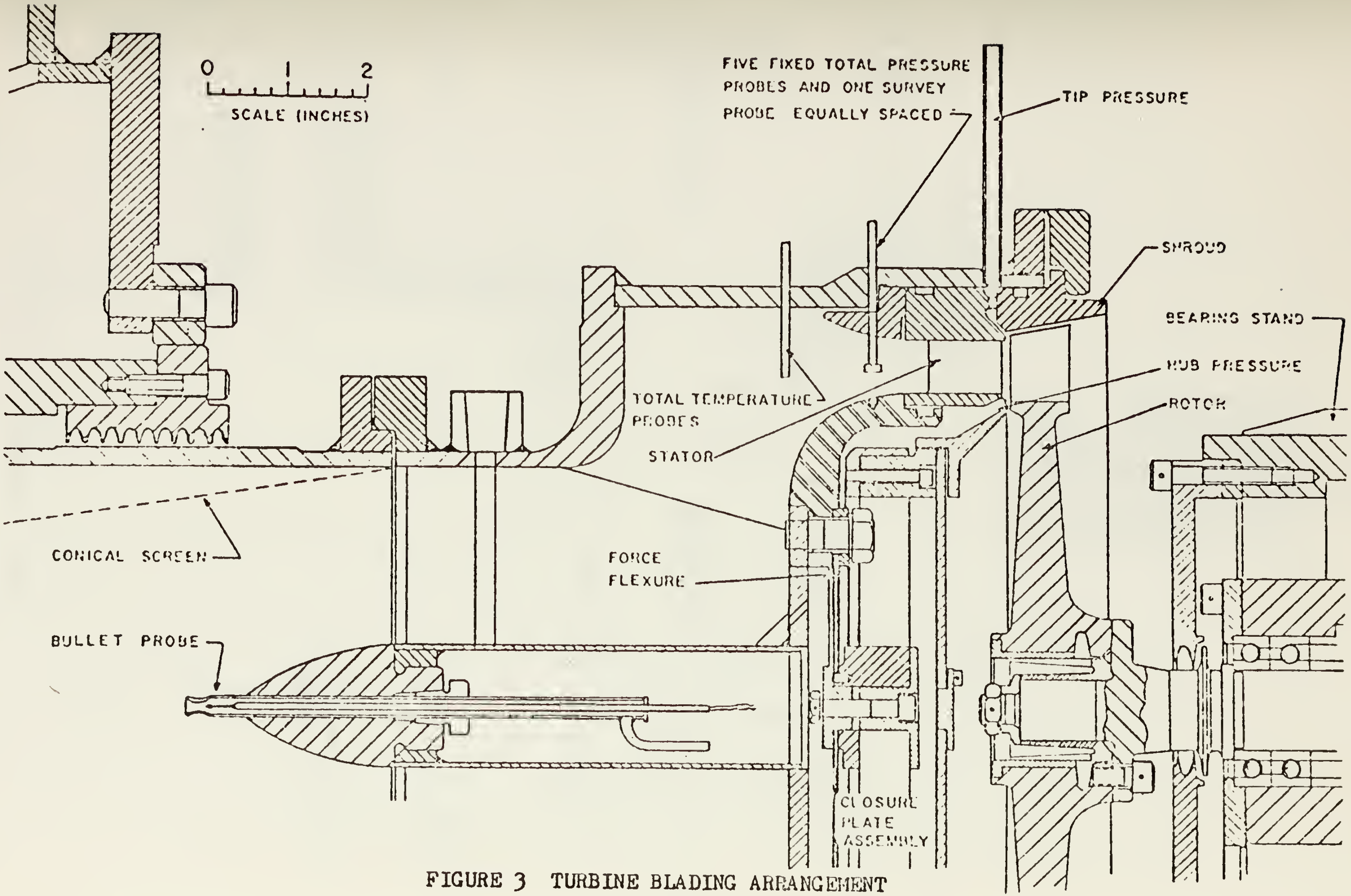


FIGURE 3 TURBINE BLADING ARRANGEMENT

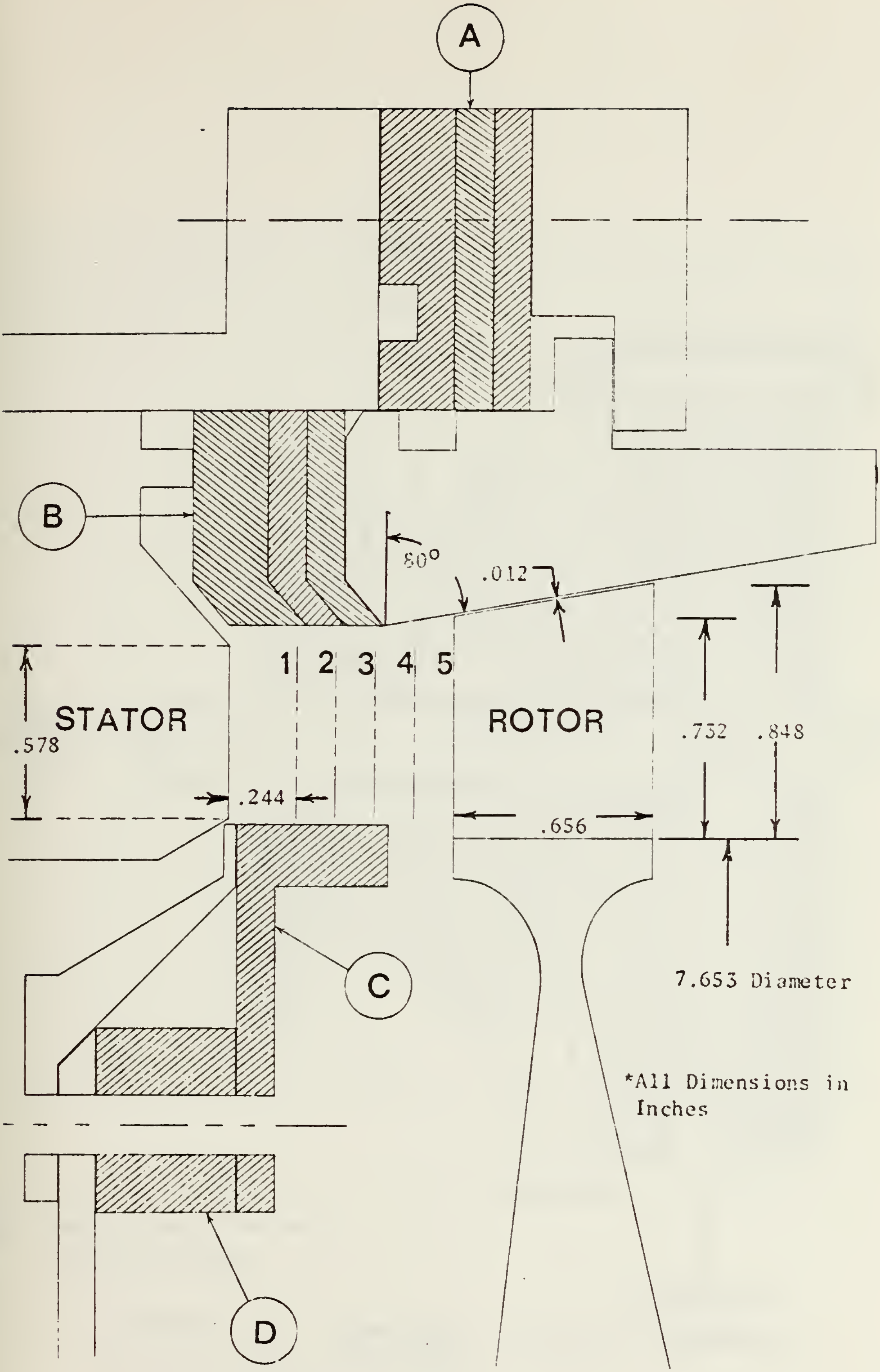
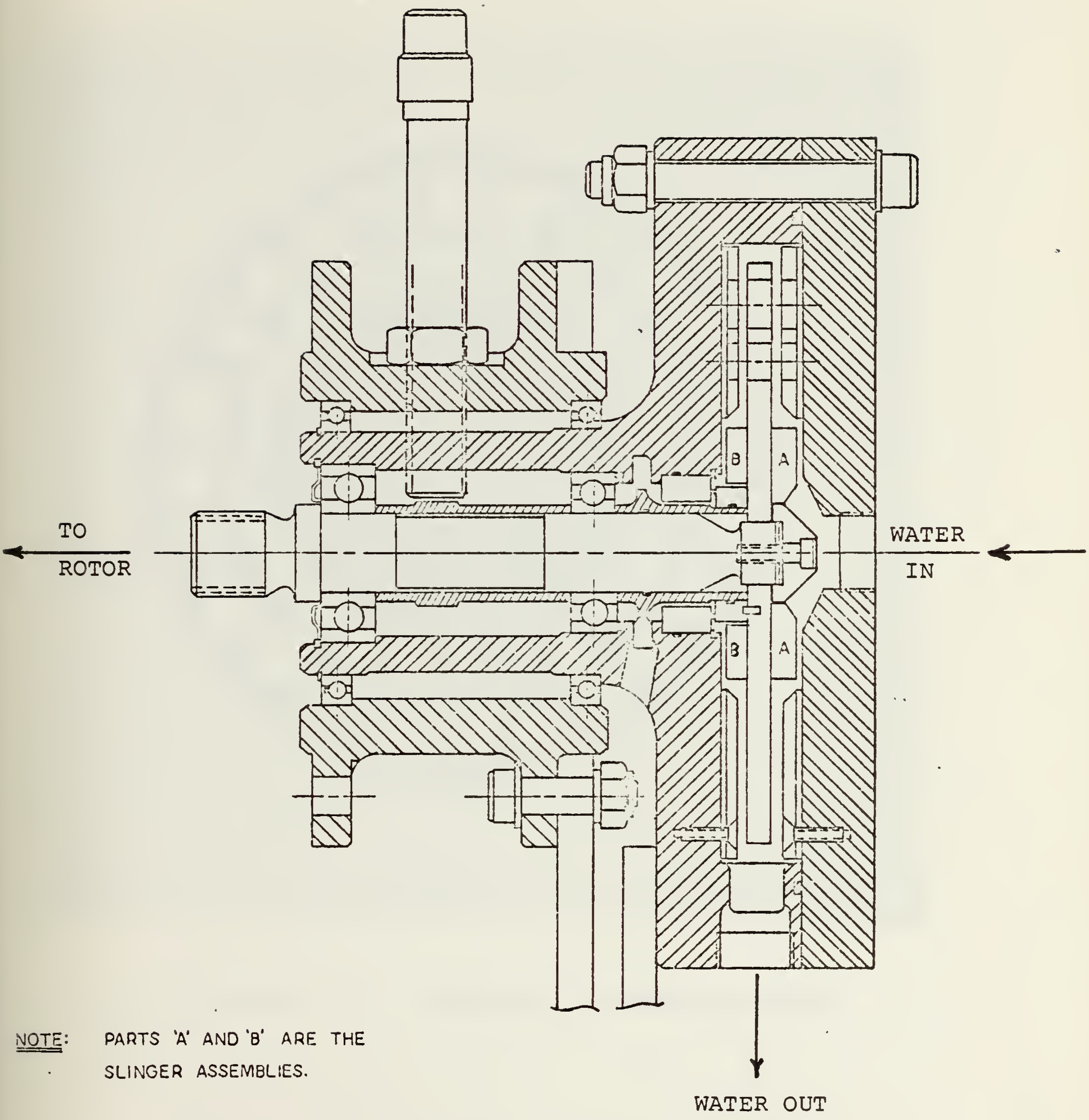


FIGURE 4. INTERBLADE PASSAGE



NOTE: PARTS 'A' AND 'B' ARE THE SLINGER ASSEMBLIES.

FIGURE 5. a) Waterbrake "Slinger" Assemblies - Side View

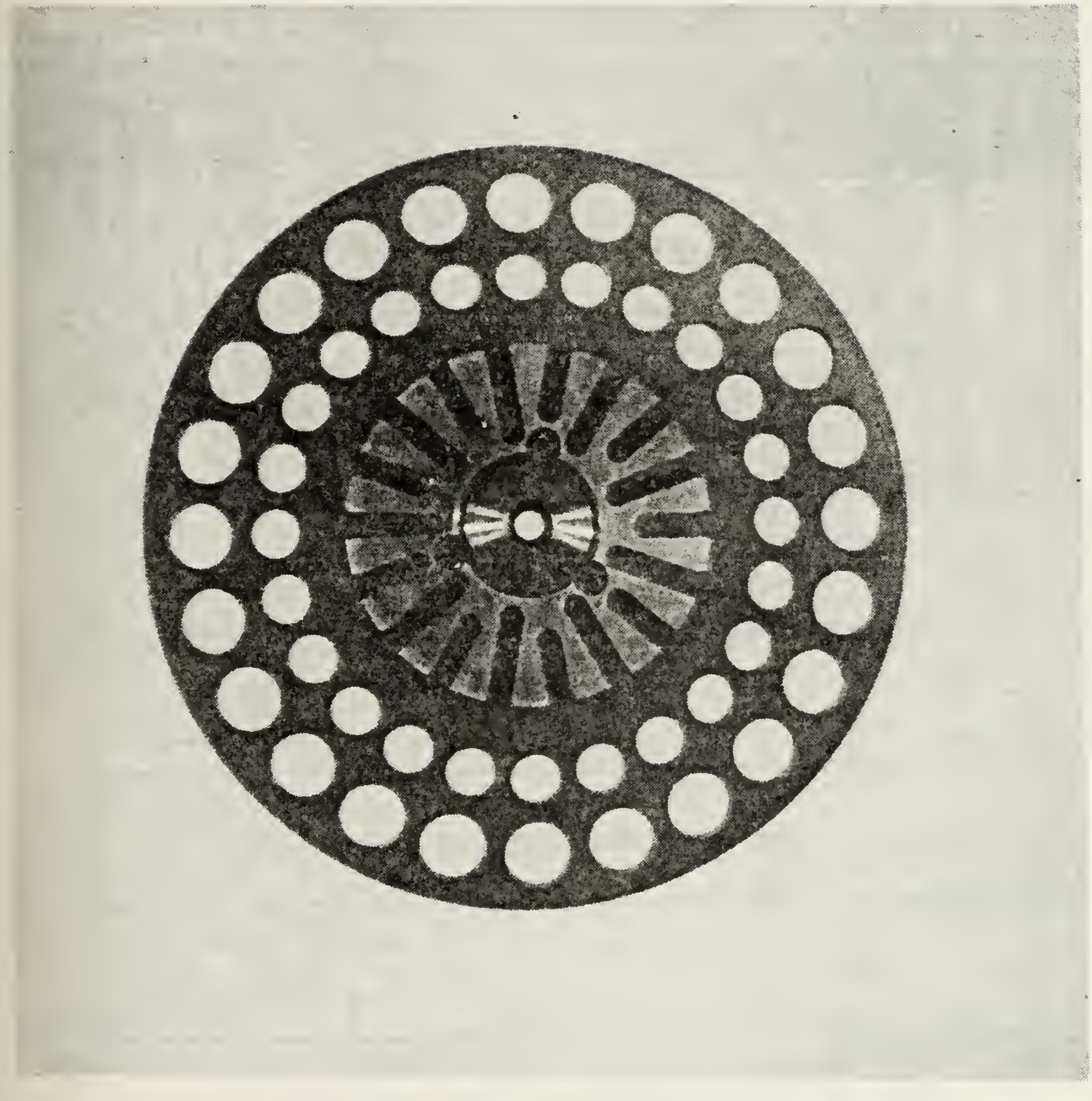


FIGURE 5. b) CLOSE-UP OF SLINGER ASSEMBLY

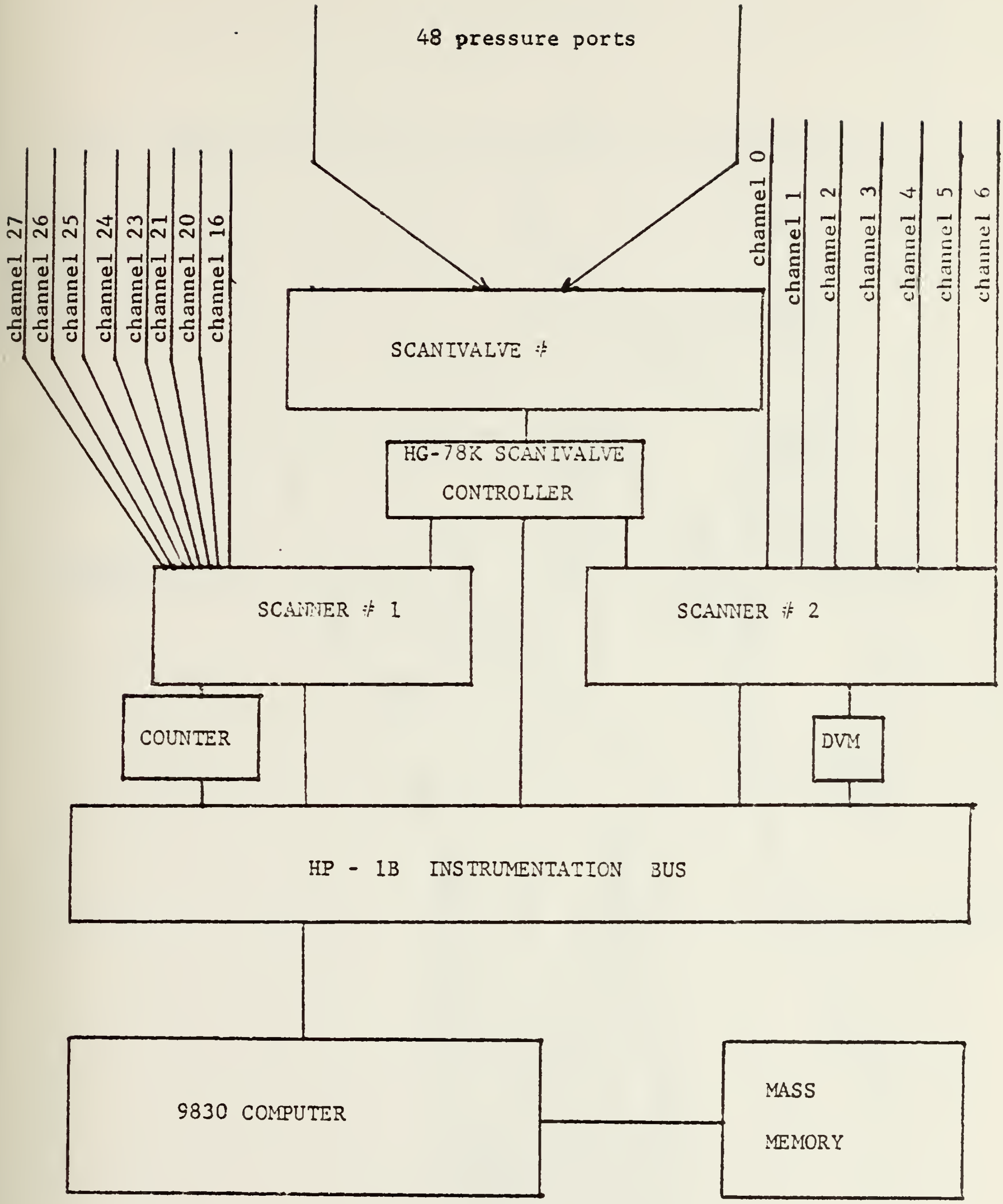


FIGURE 6. Instrumentation System

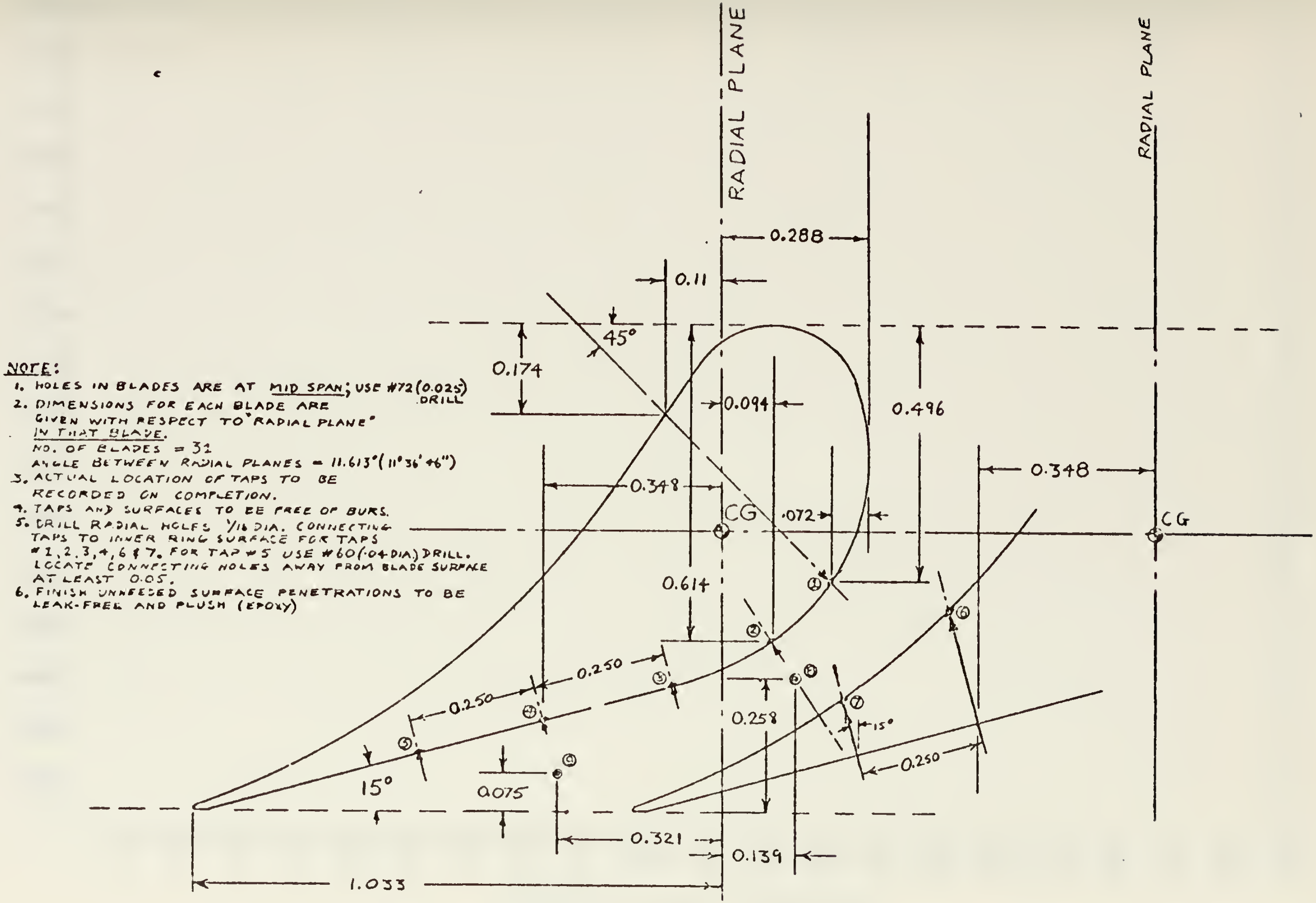


FIGURE 7. STATOR PRESSURE TAP LOCATIONS

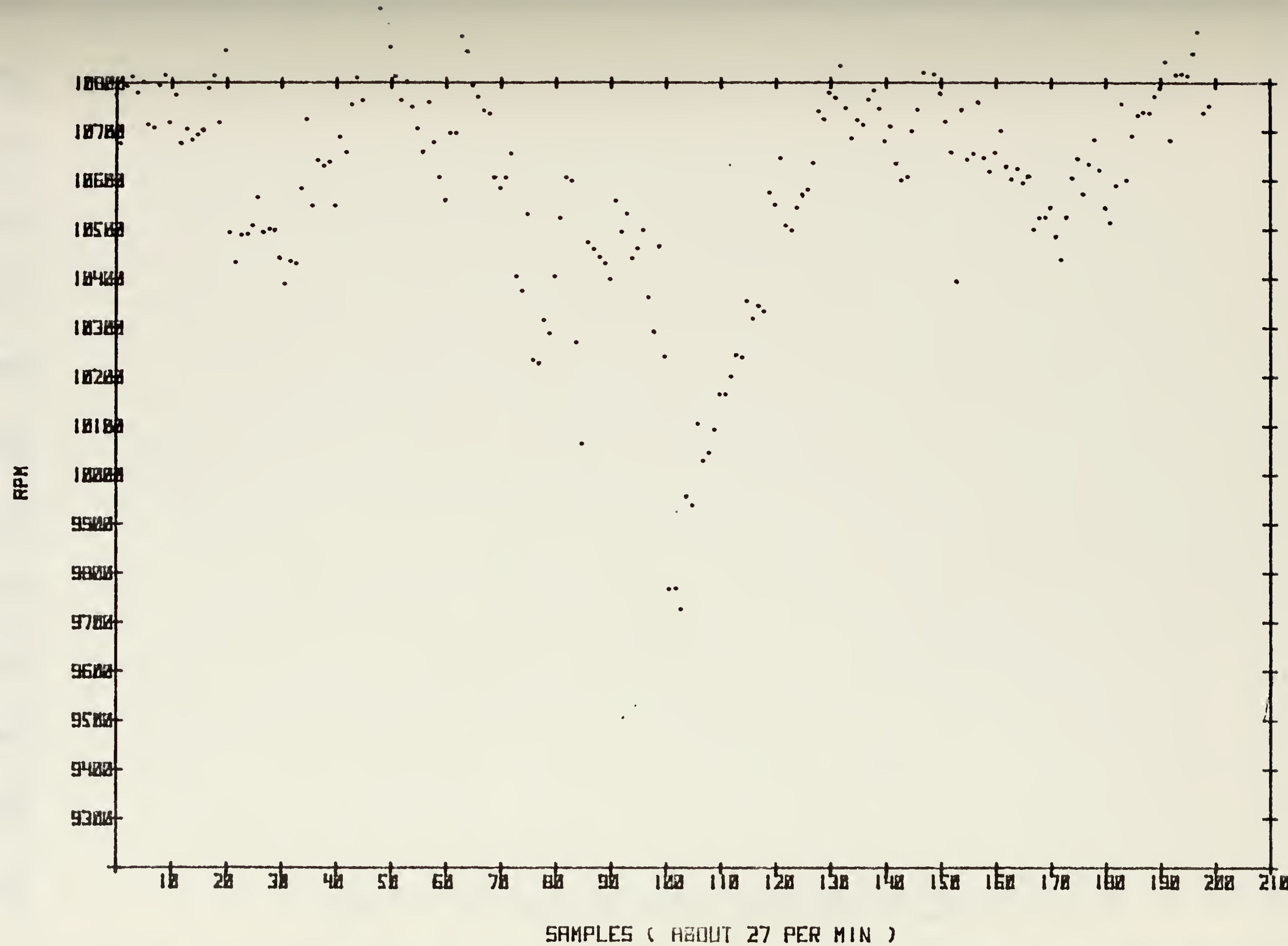


FIGURE 8. RPM SAMPLES (10610 RPM, No slinger)

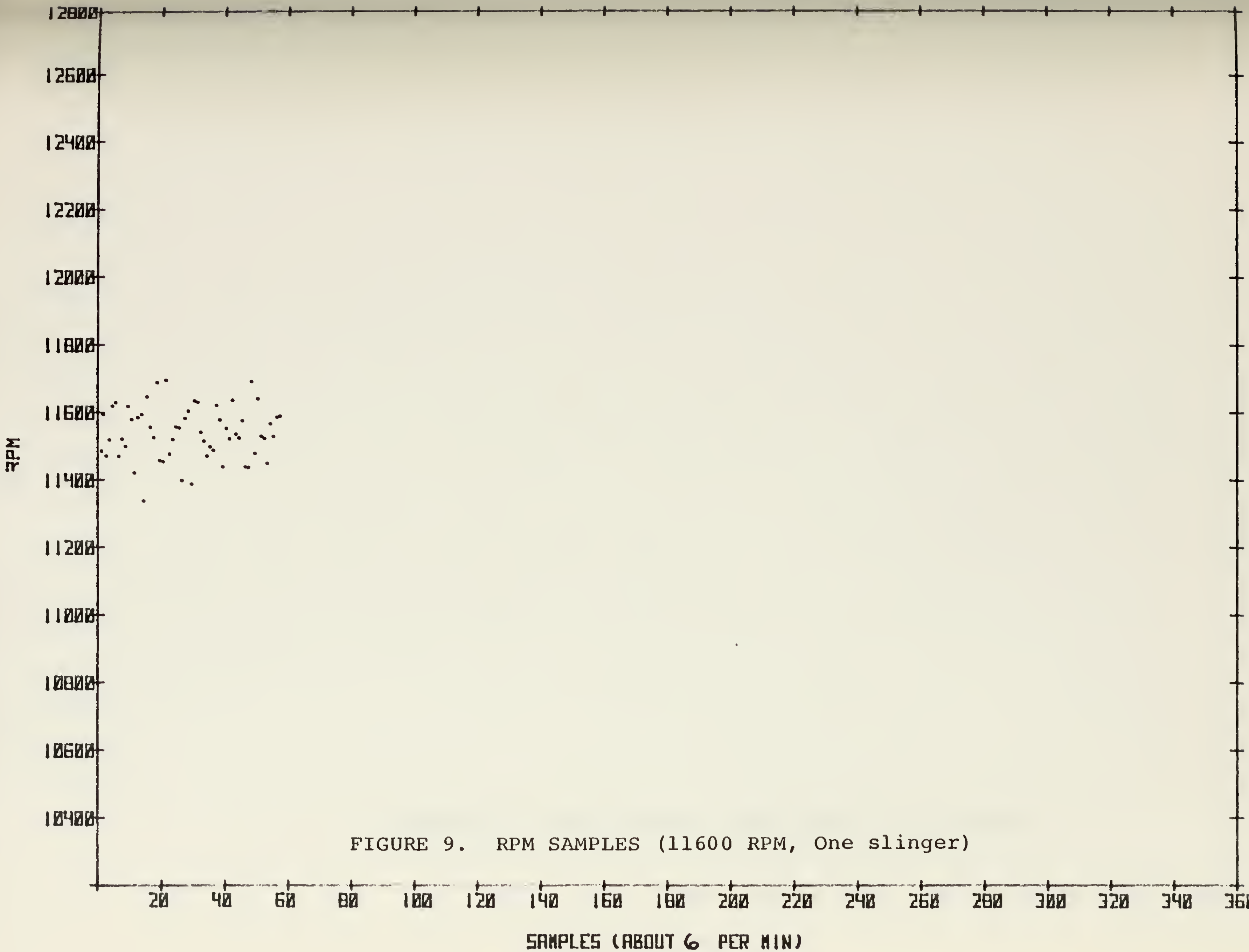


FIGURE 9. RPM SAMPLES (11600 RPM, One slinger)

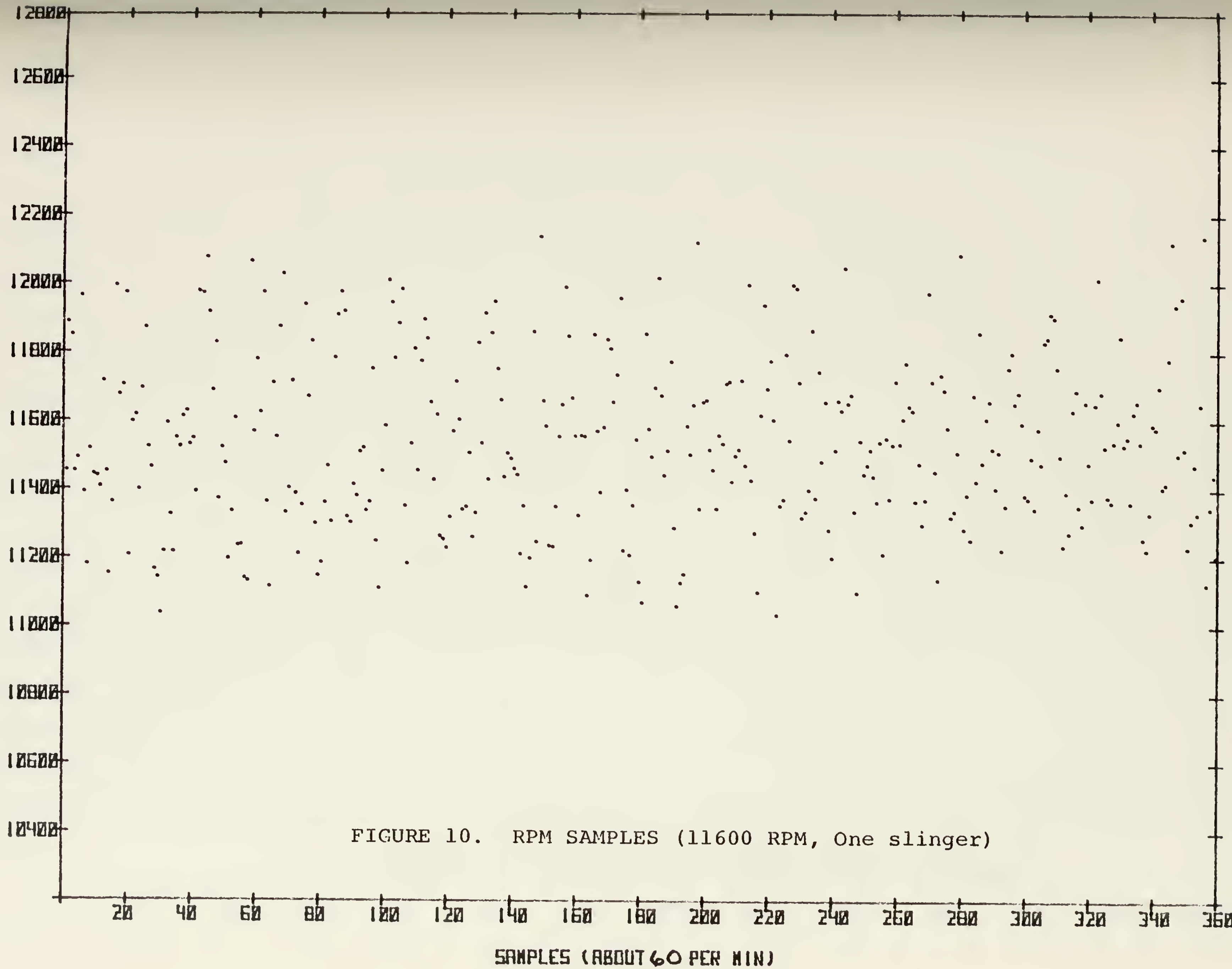


FIGURE 10. RPM SAMPLES (11600 RPM, One slinger)

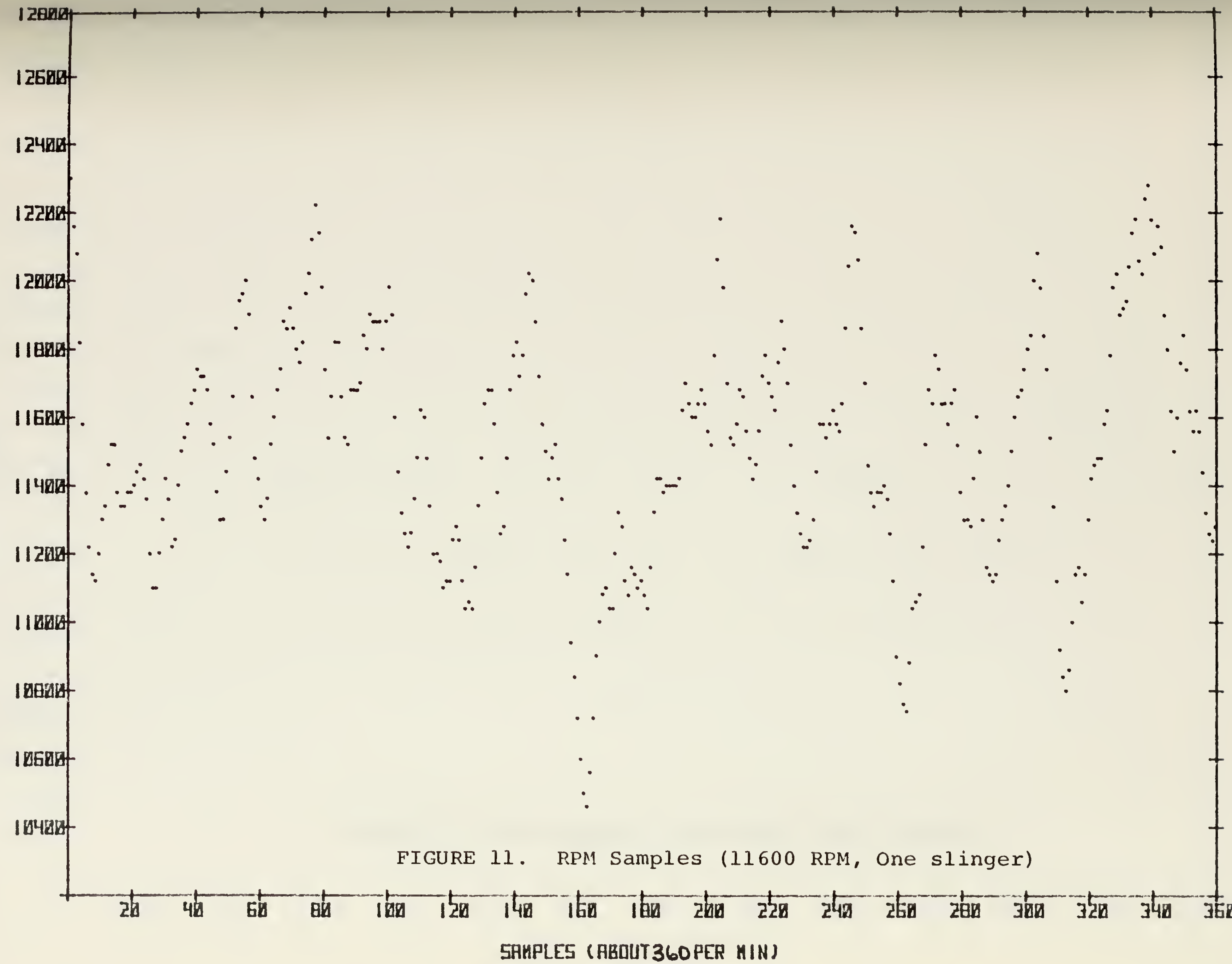


FIGURE 11. RPM Samples (11600 RPM, One slinger)

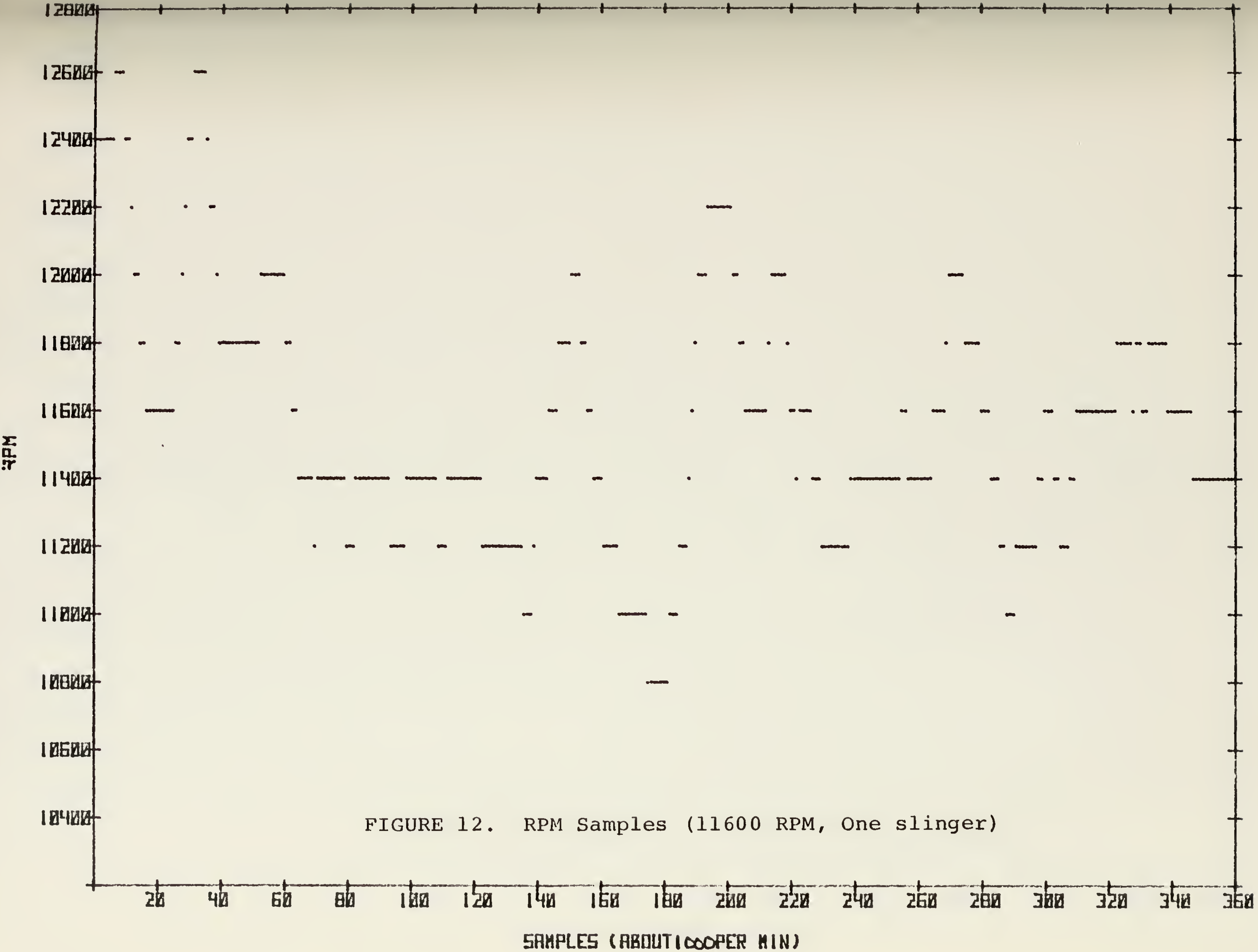


FIGURE 12. RPM Samples (11600 RPM, One slinger)

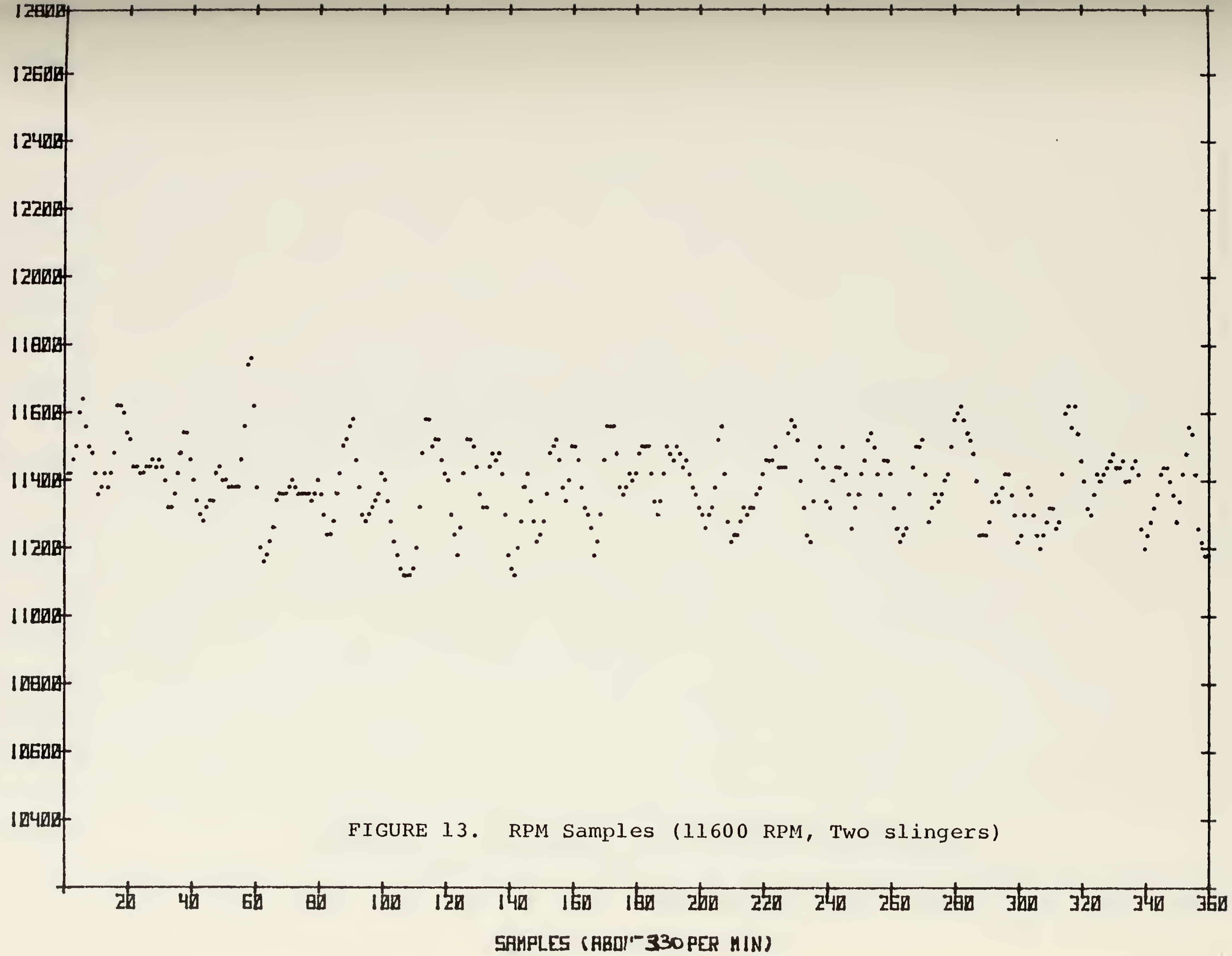


FIGURE 13. RPM Samples (11600 RPM, Two slingers)

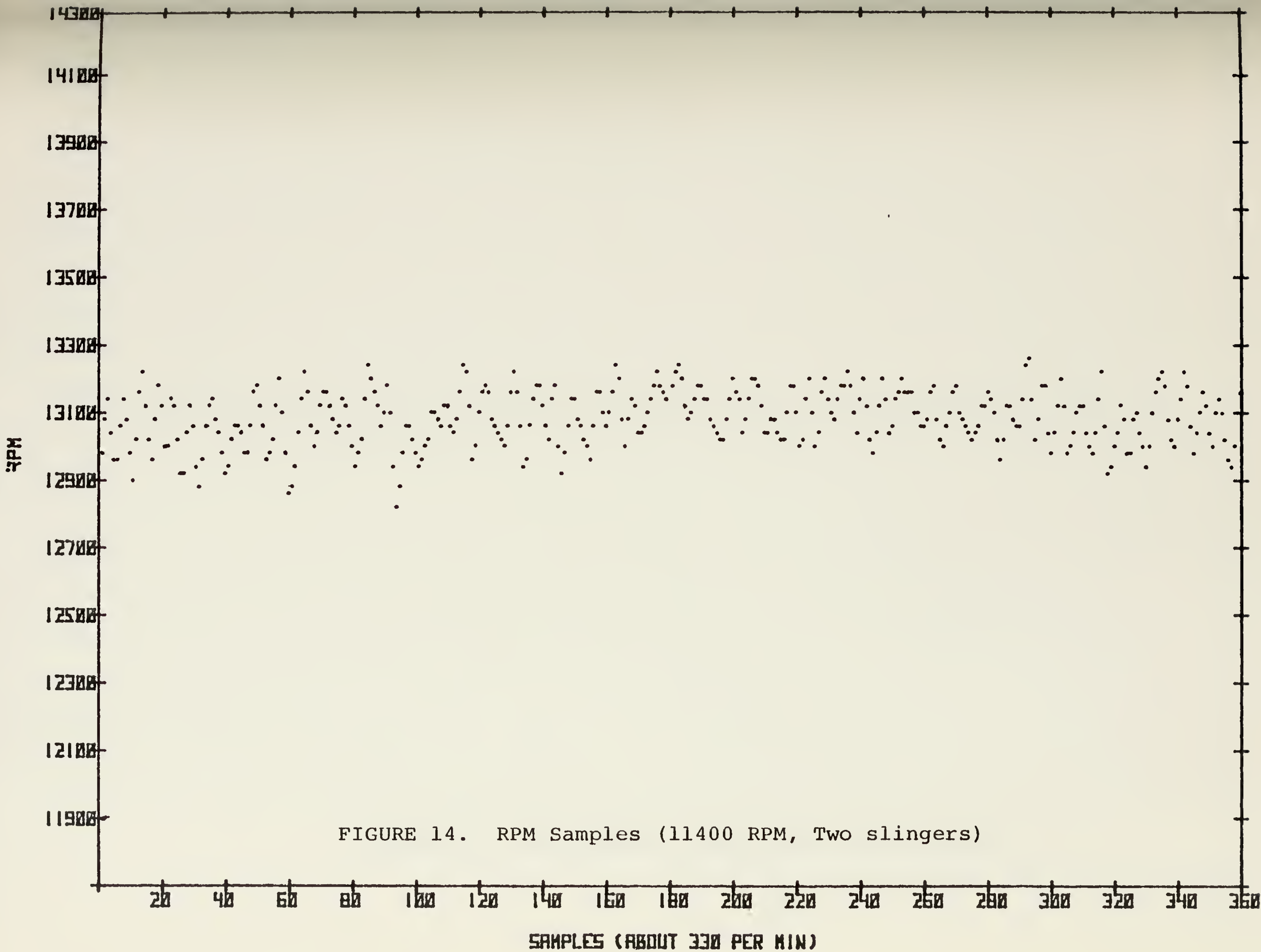


FIGURE 14. RPM Samples (11400 RPM, Two slingers)

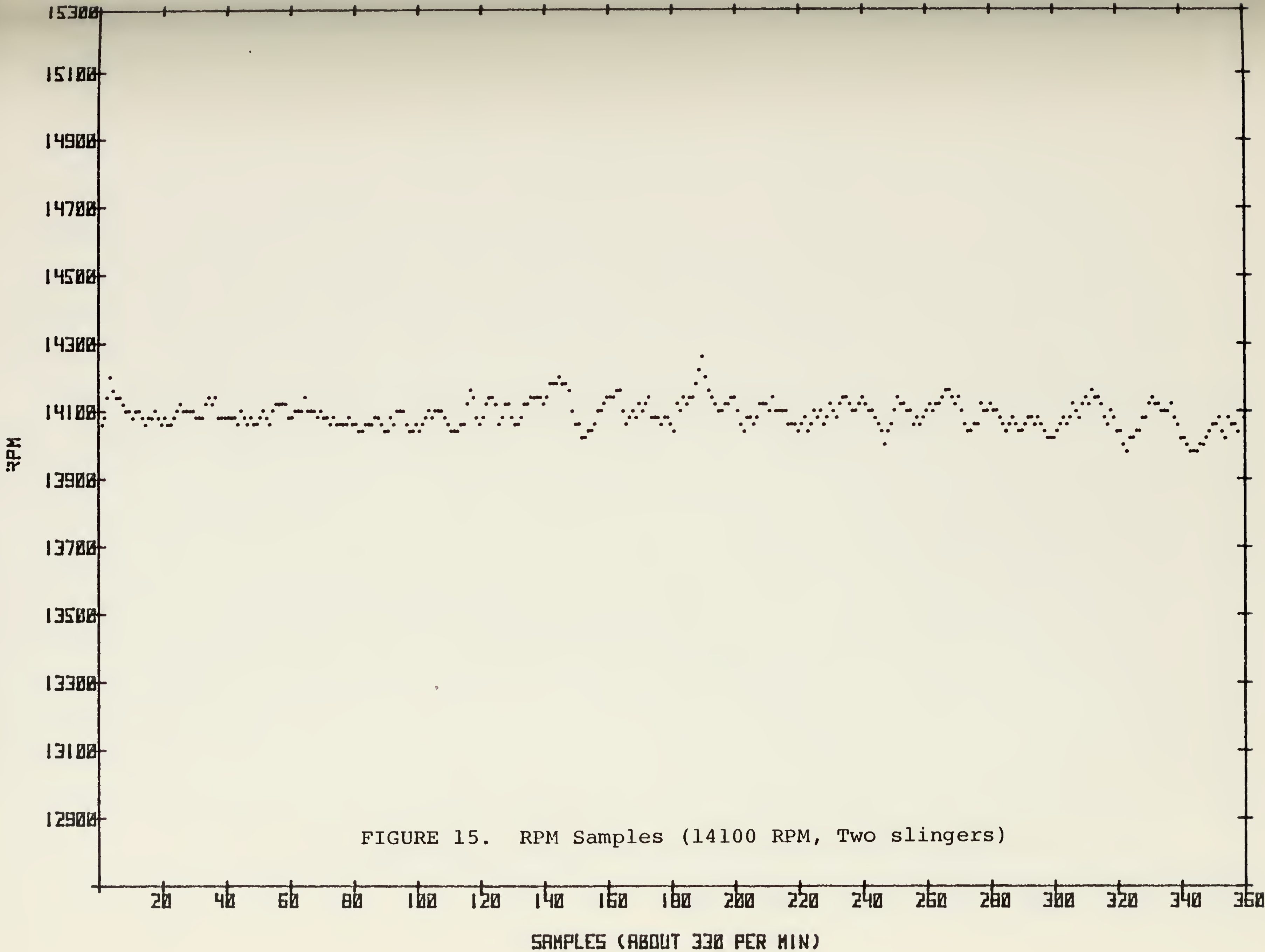


FIGURE 15. RPM Samples (14100 RPM, Two slingers)

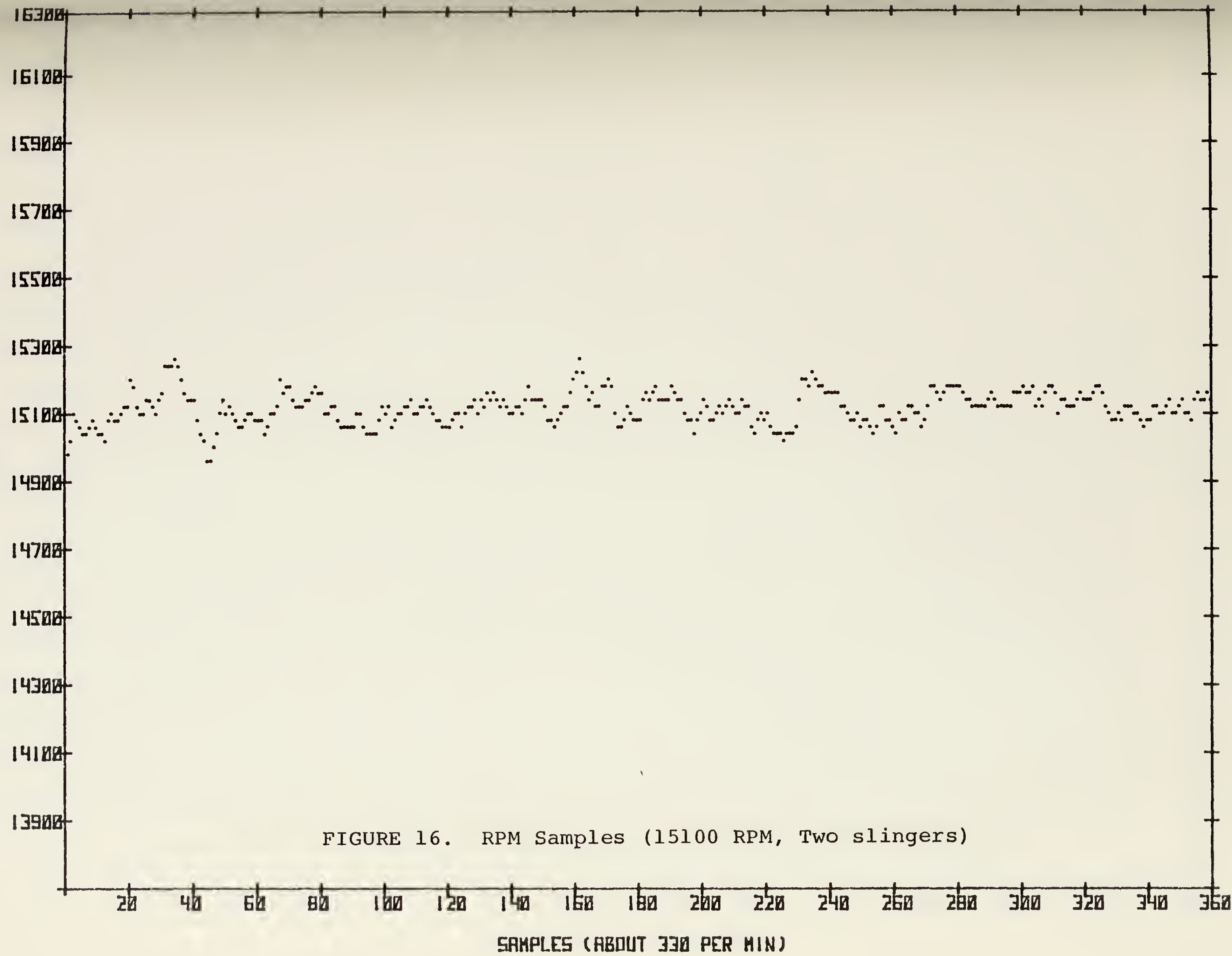


FIGURE 16. RPM Samples (15100 RPM, Two slingers)

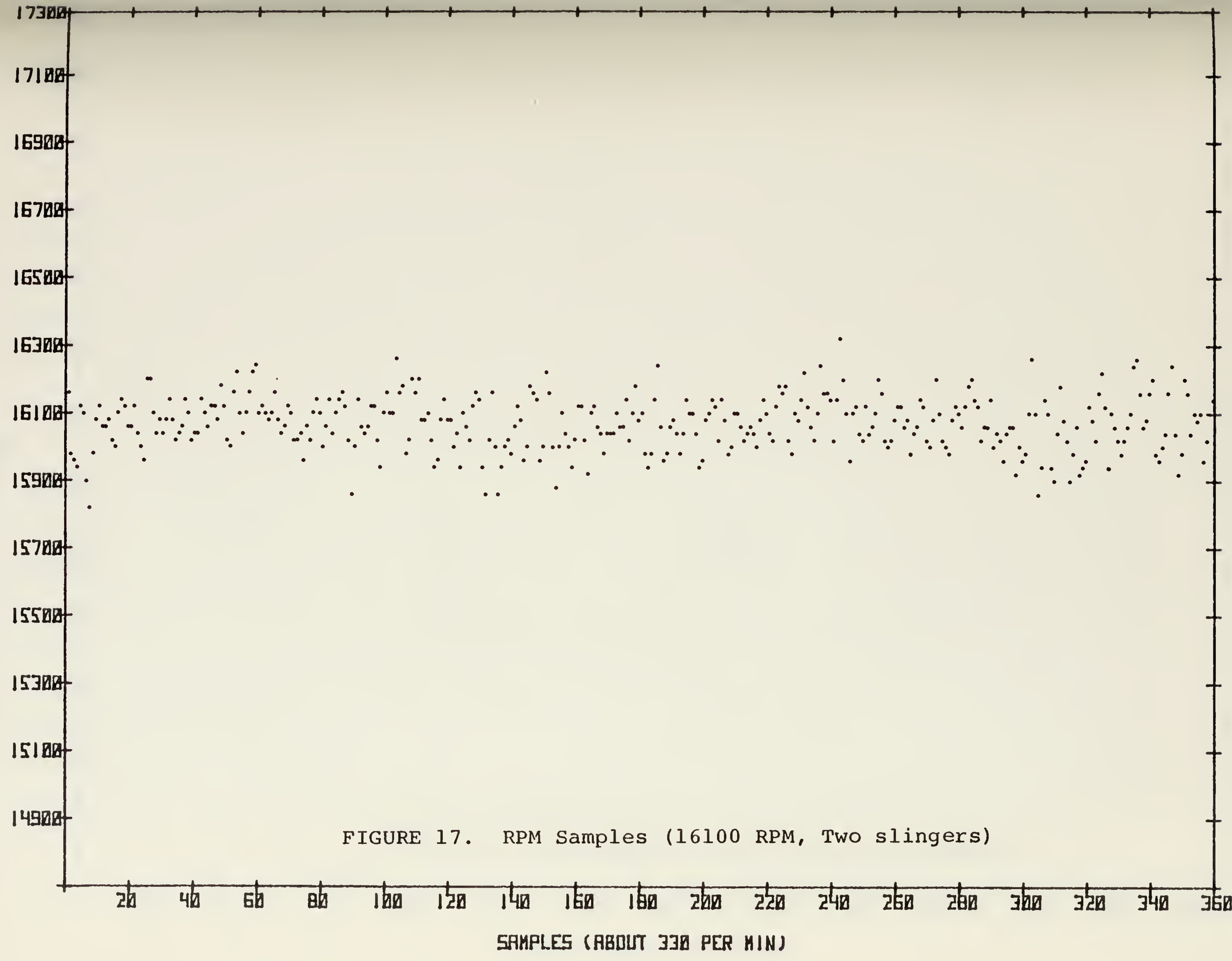


FIGURE 17. RPM Samples (16100 RPM, Two slingers)

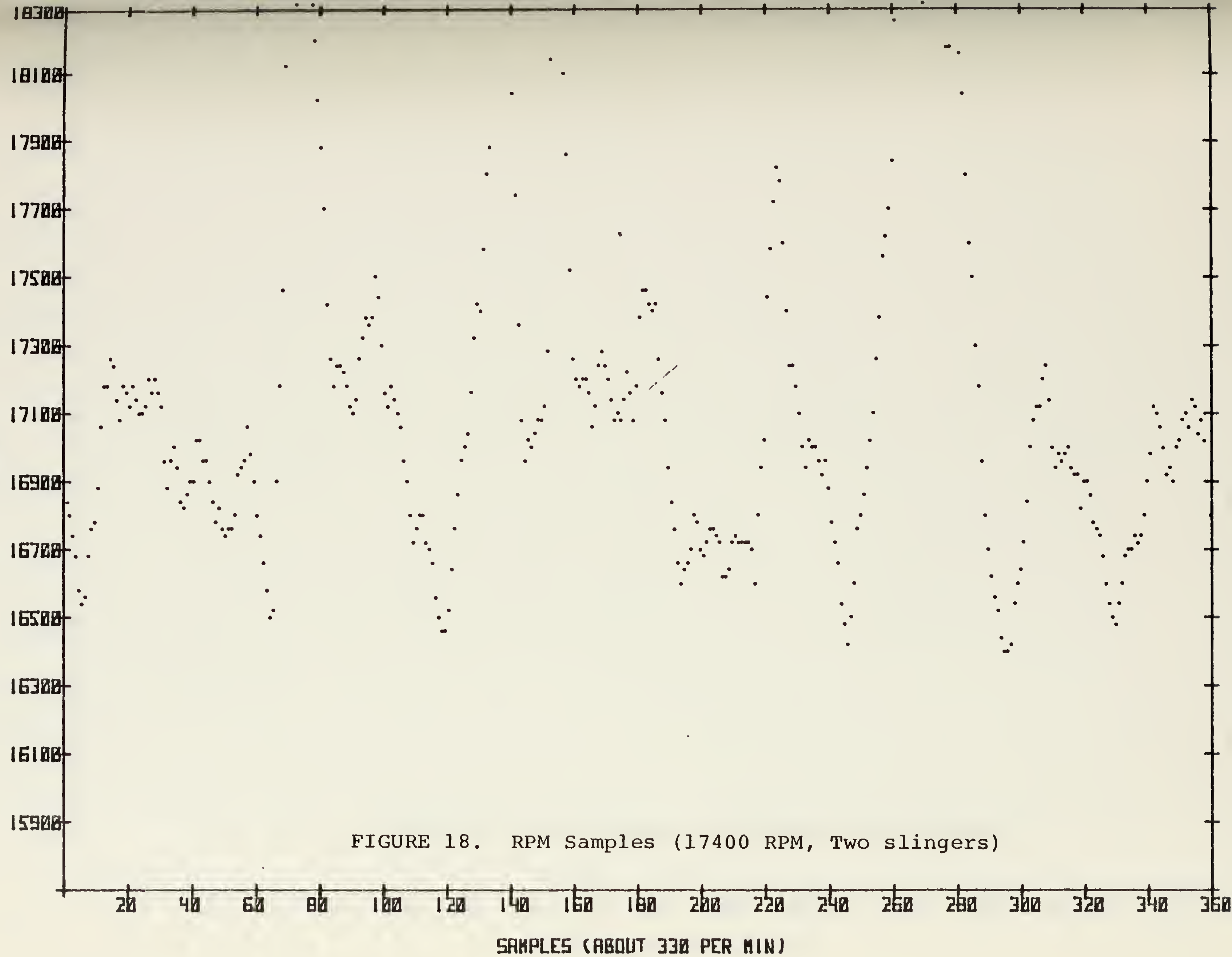


FIGURE 18. RPM Samples (17400 RPM, Two slingers)

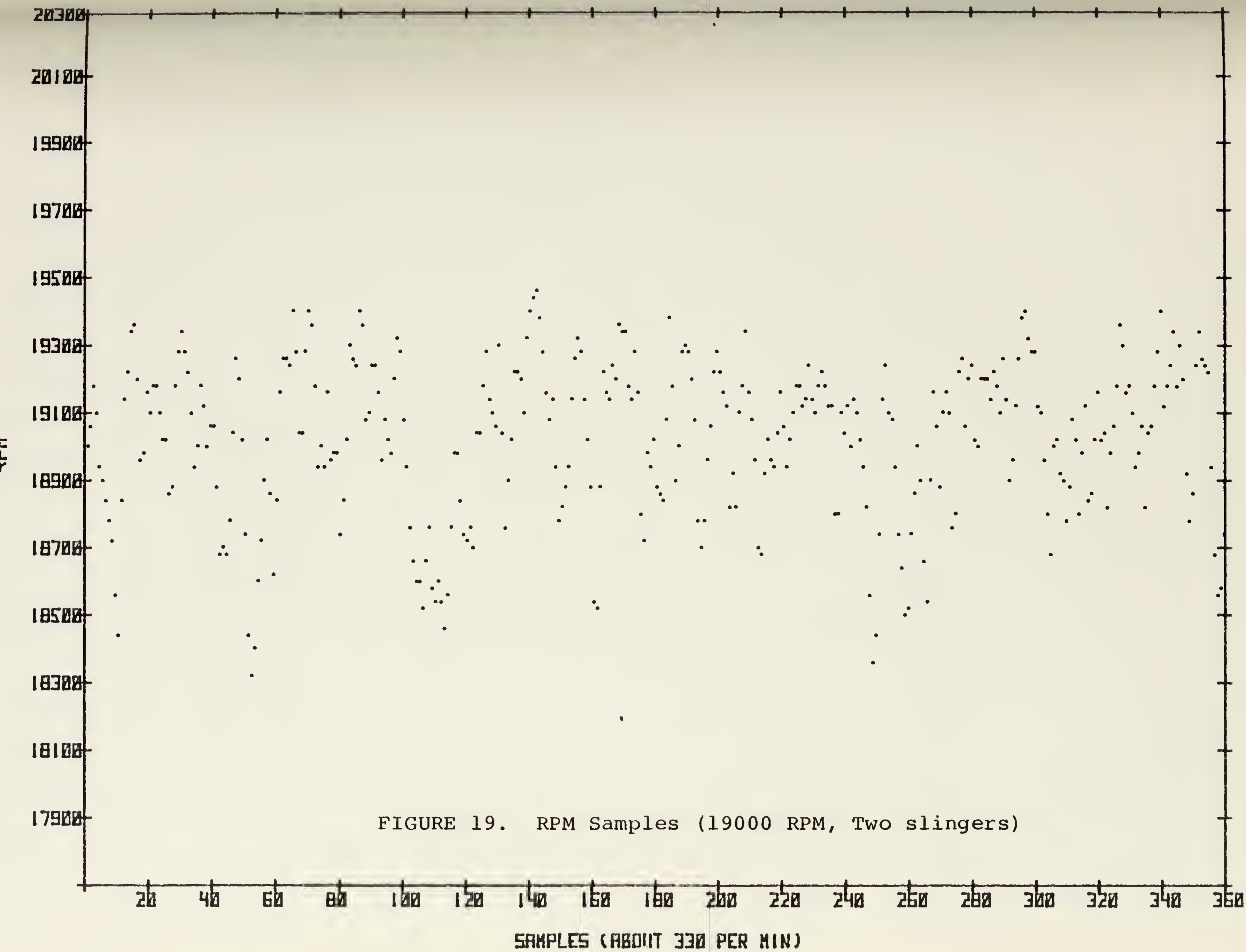


FIGURE 19. RPM Samples (19000 RPM, Two slingers)

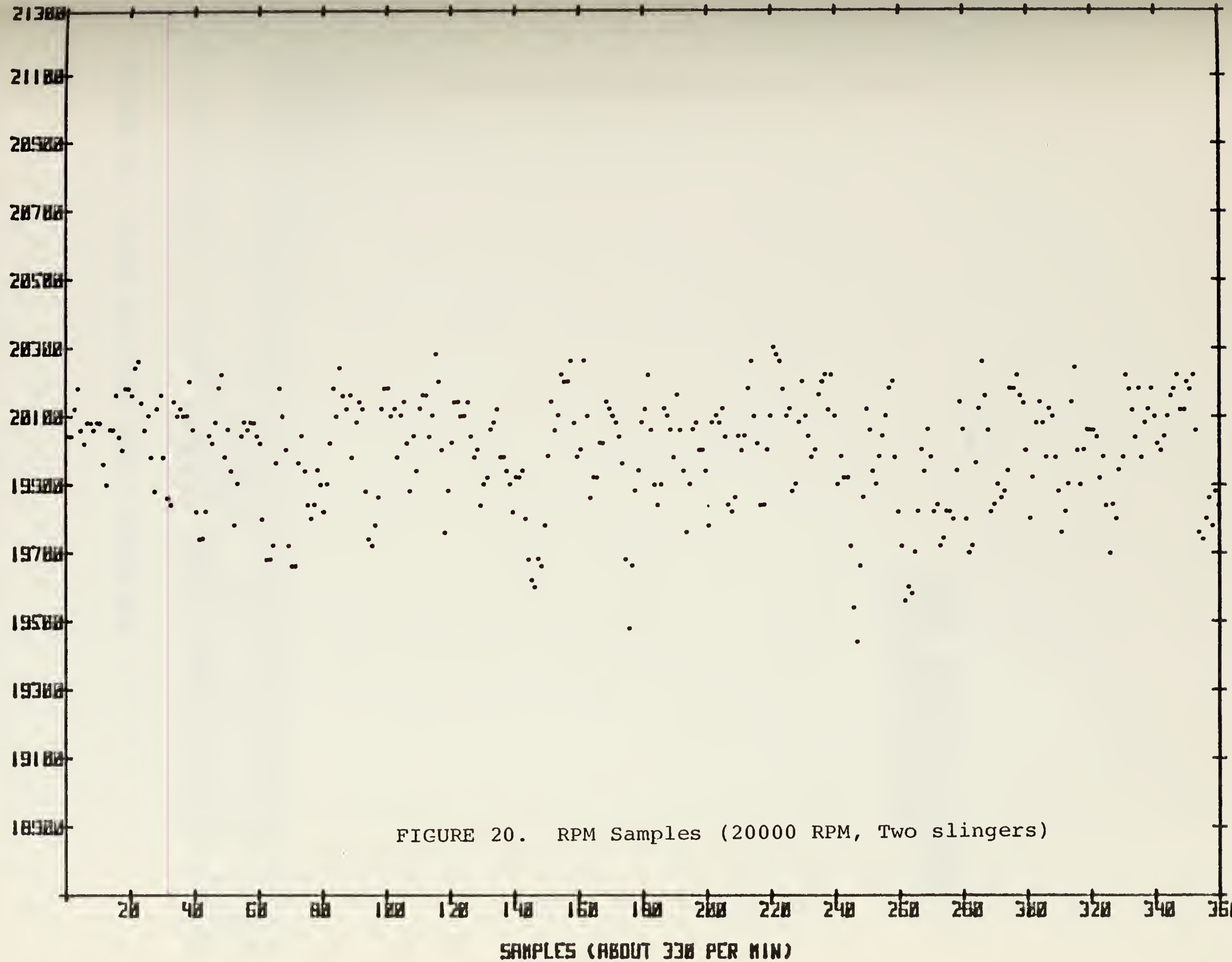


FIGURE 20. RPM Samples (20000 RPM, Two slingers)

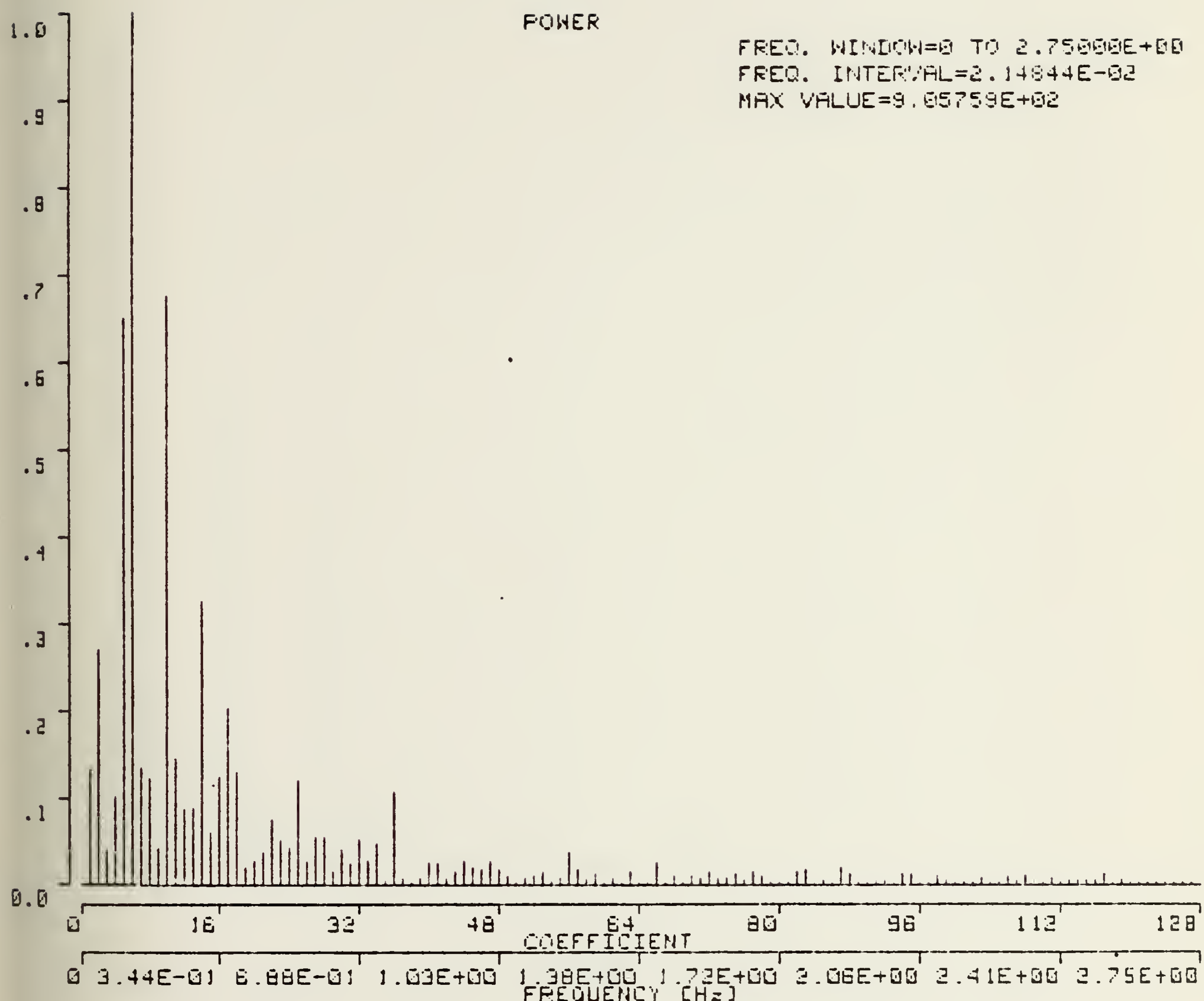


FIGURE 21. POWER SPECTRUM DATA - 15000 RPM

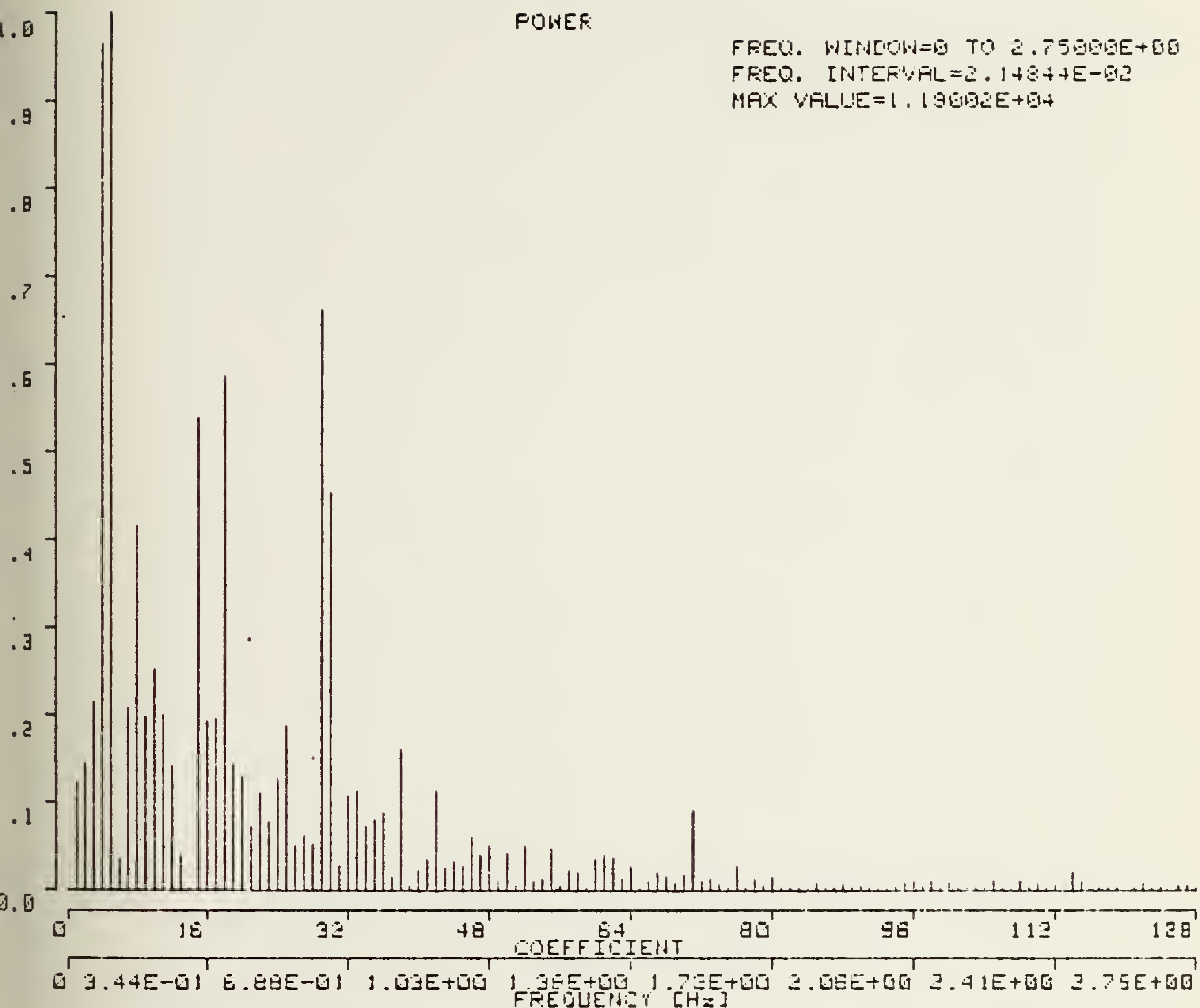


FIGURE 22. POWER SPECTRUM DATA - 19000 RPM

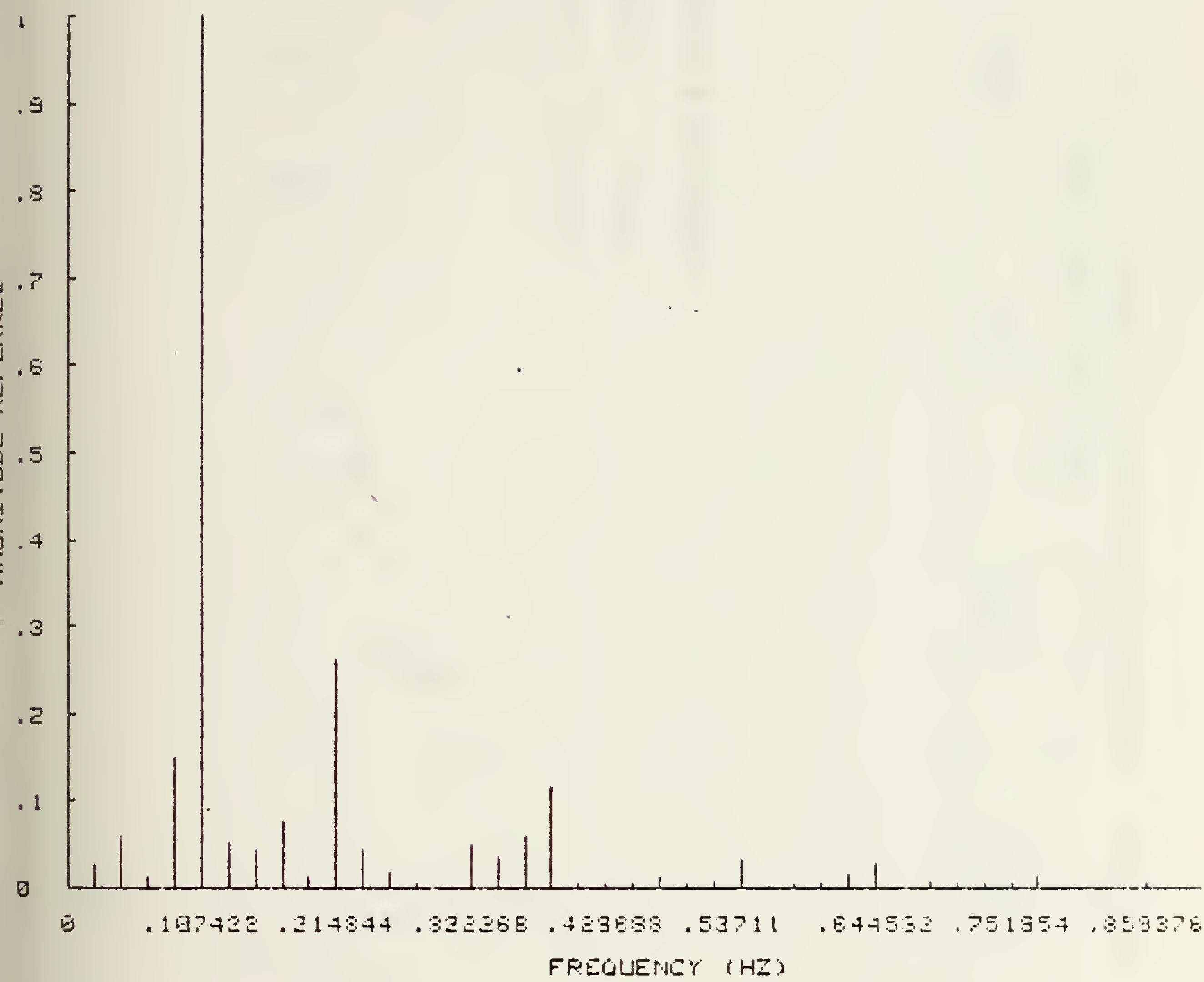


FIGURE 23. POWER SPECTRUM CORRELATION (15000/19000 RPM)

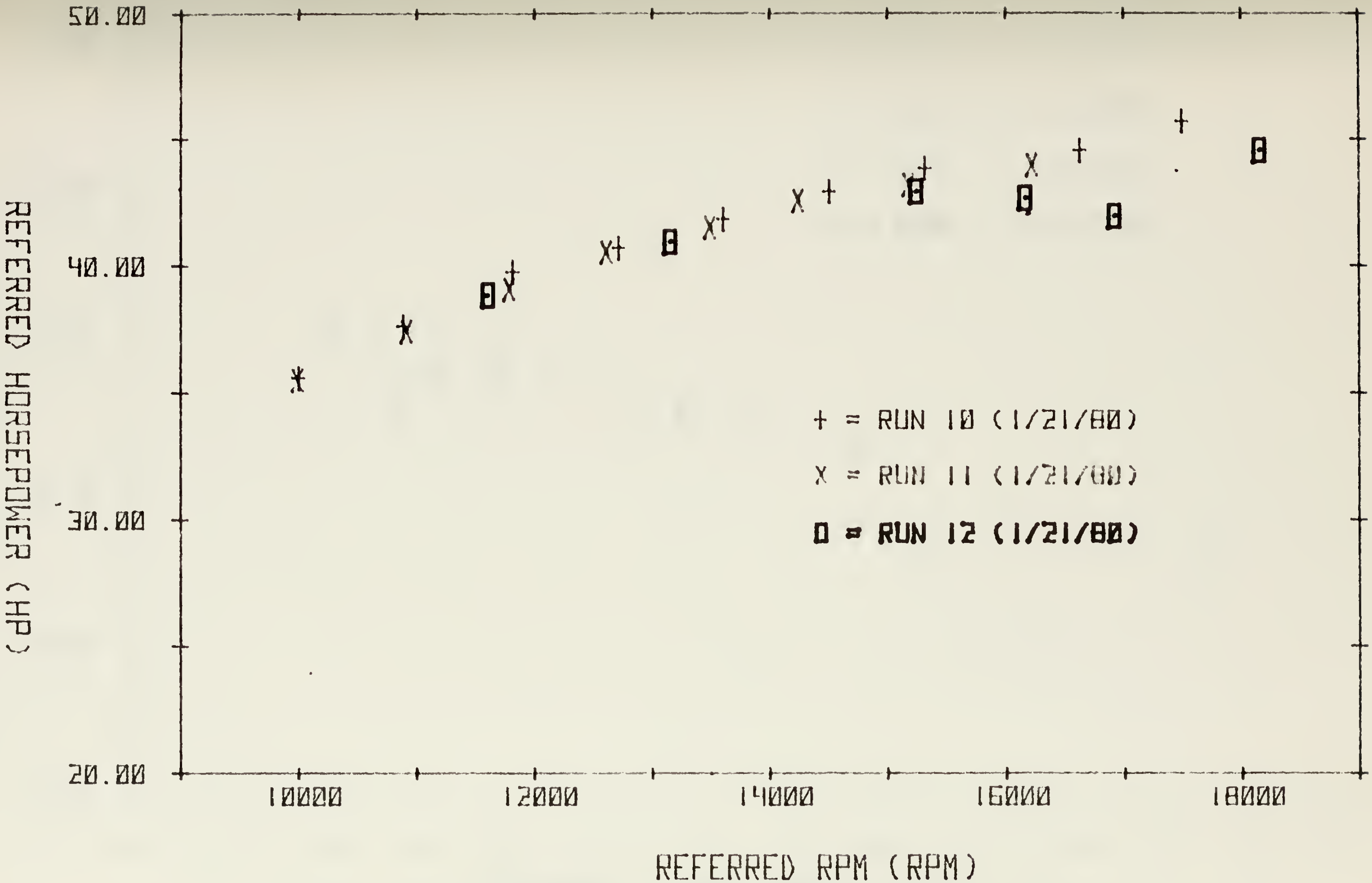


FIGURE 24. REFERRED HORSEPOWER vs. REFERRED RPM (PR=3.5)

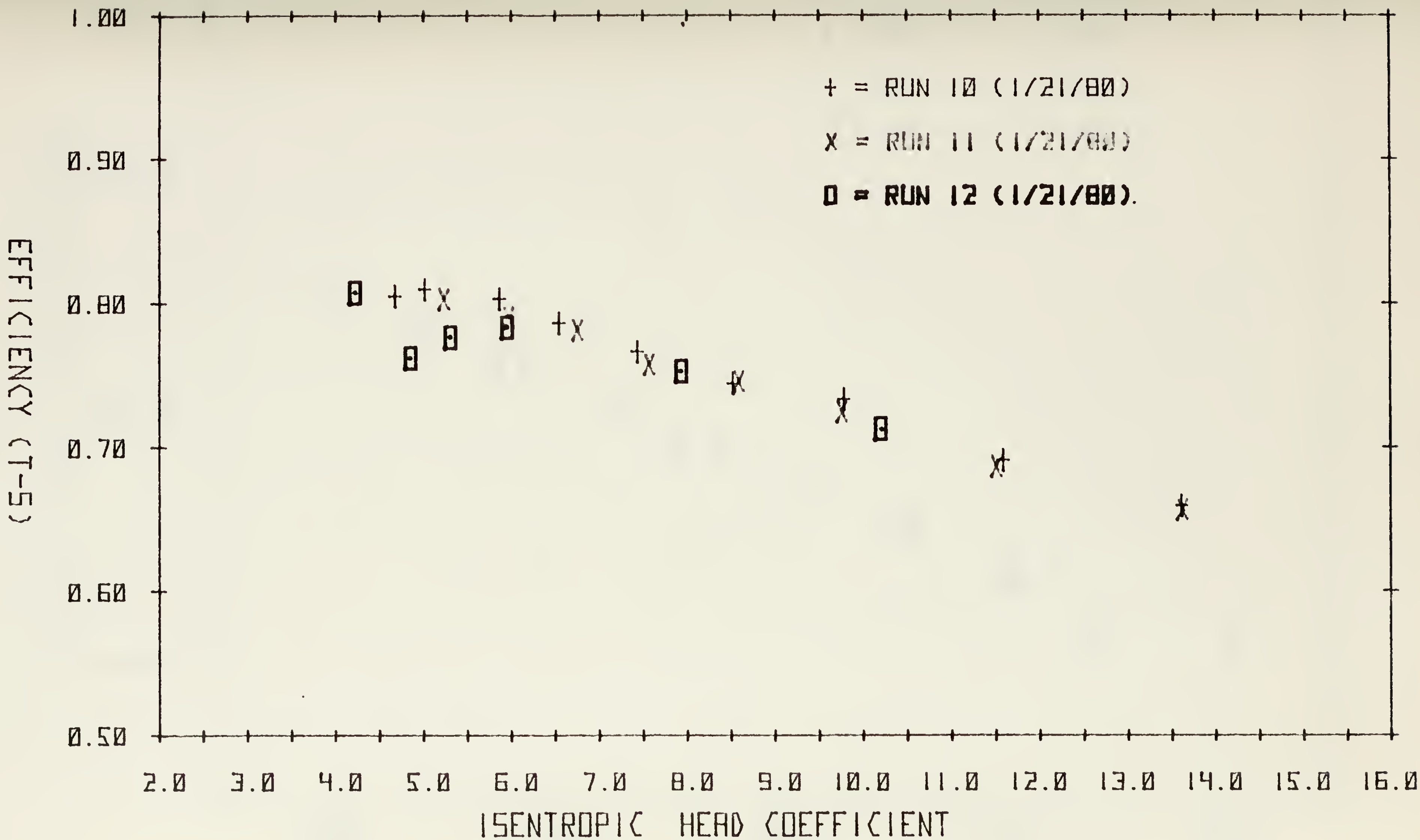


FIGURE 25. EFFICIENCY (T-S) vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5)

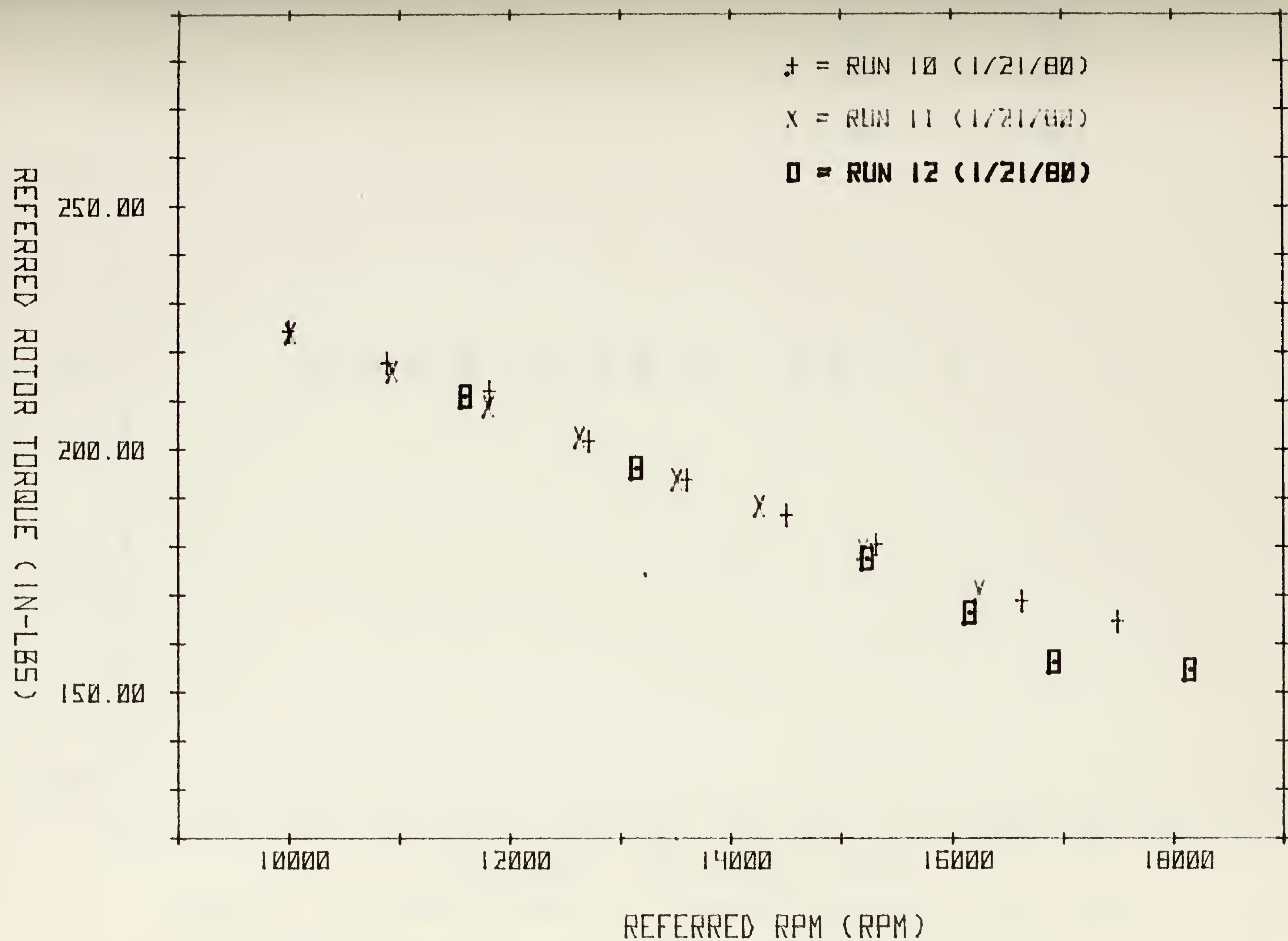


FIGURE 26. REFERRED ROTOR TORQUE vs. REFERRED RPM (PR=3.5)

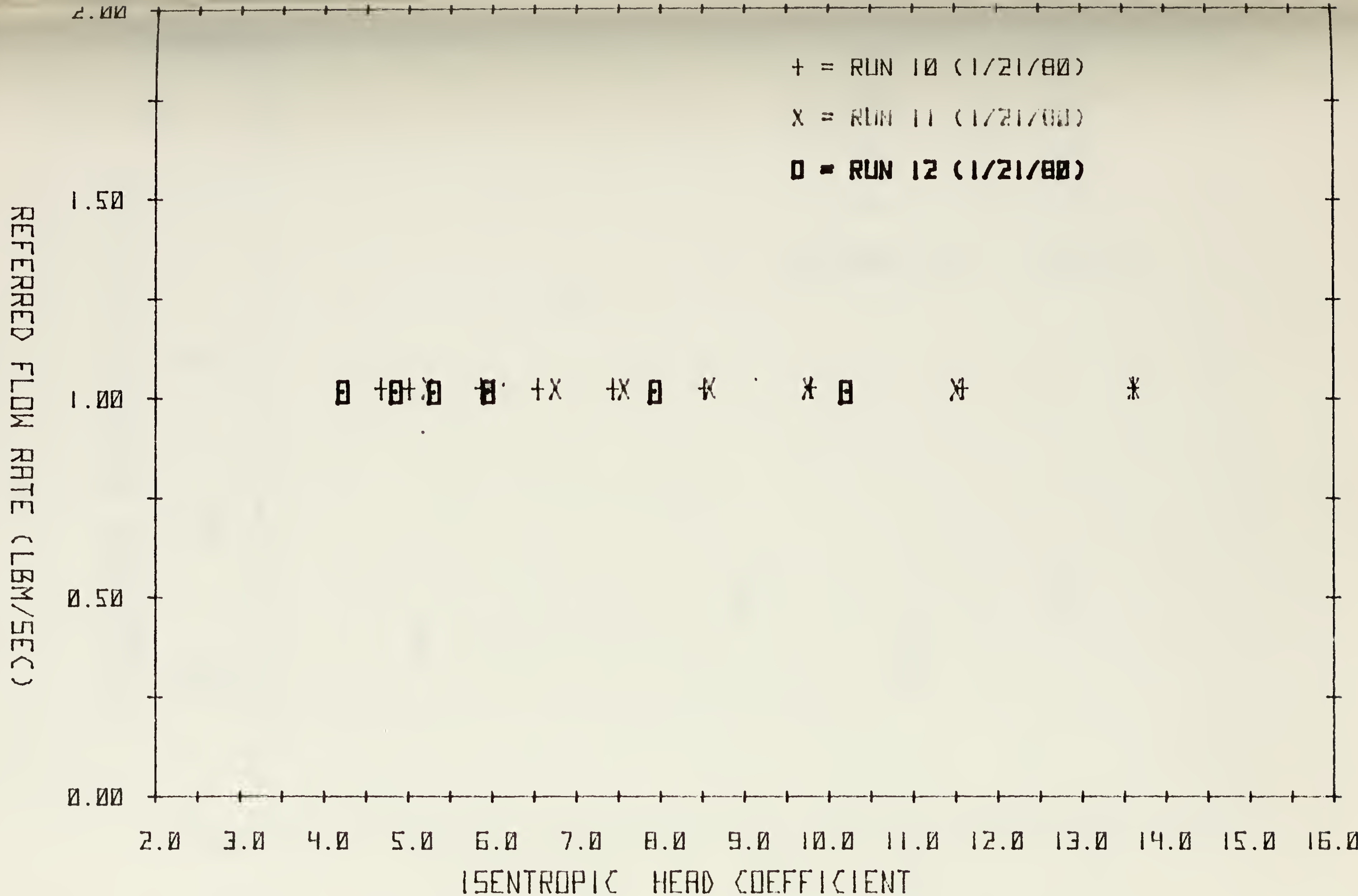


FIGURE 27. REFERRED FLOW RATE vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5)

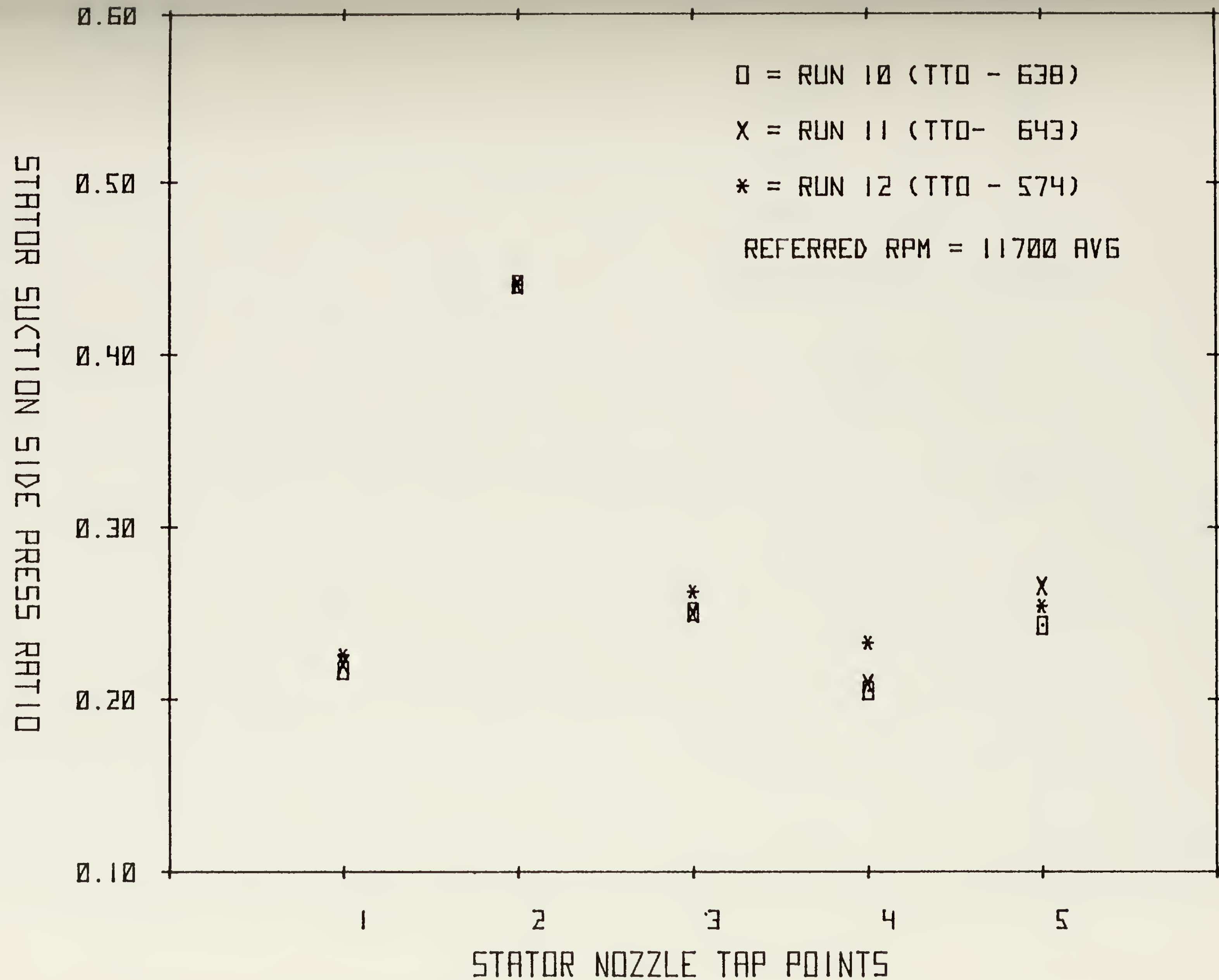


FIGURE 28. STATOR SUCTION SIDE PRESSURE RATIO vs. STATOR NOZZLE TAP POINTS - 11700 Referred RPM, PR=3.5

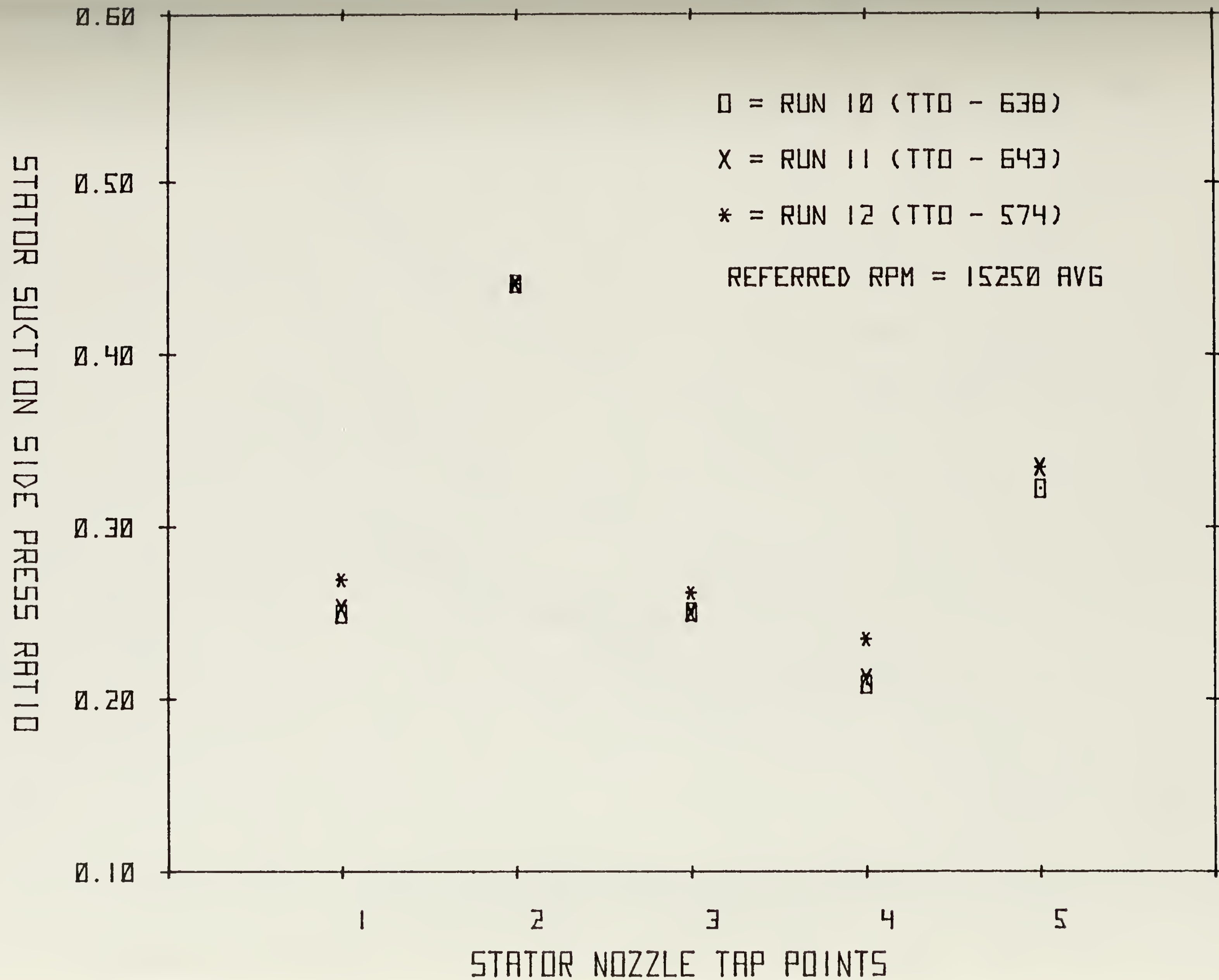


FIGURE 29. STATOR SUCTION SIDE PRESSURE RATIO vs. STATOR NOZZLE TAP POINTS - 15250 Referred RPM, PR=3.5

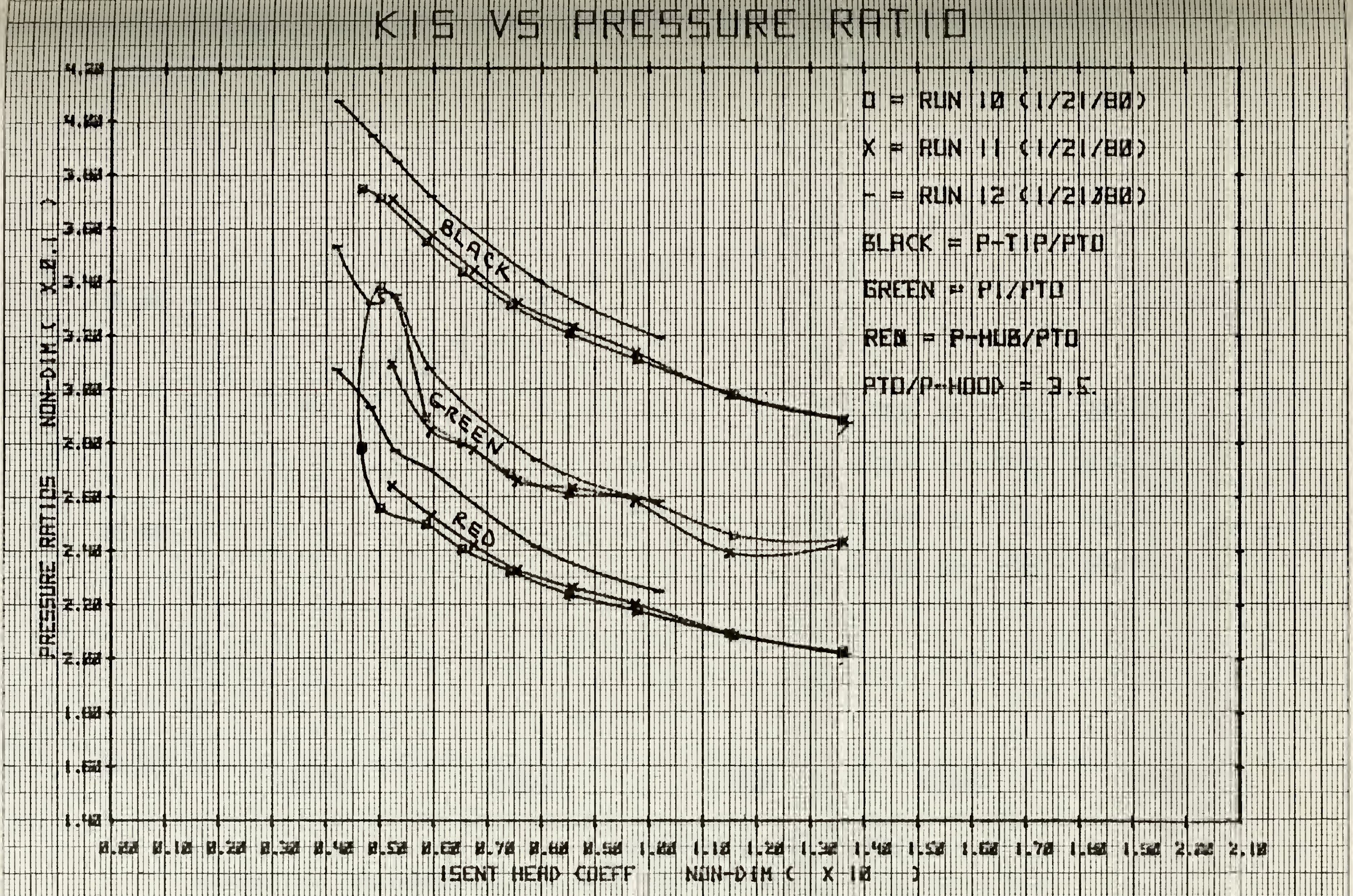


FIGURE 30. PRESSURE RATIO vs. ISENTROPIC HEAD COEFFICIENT

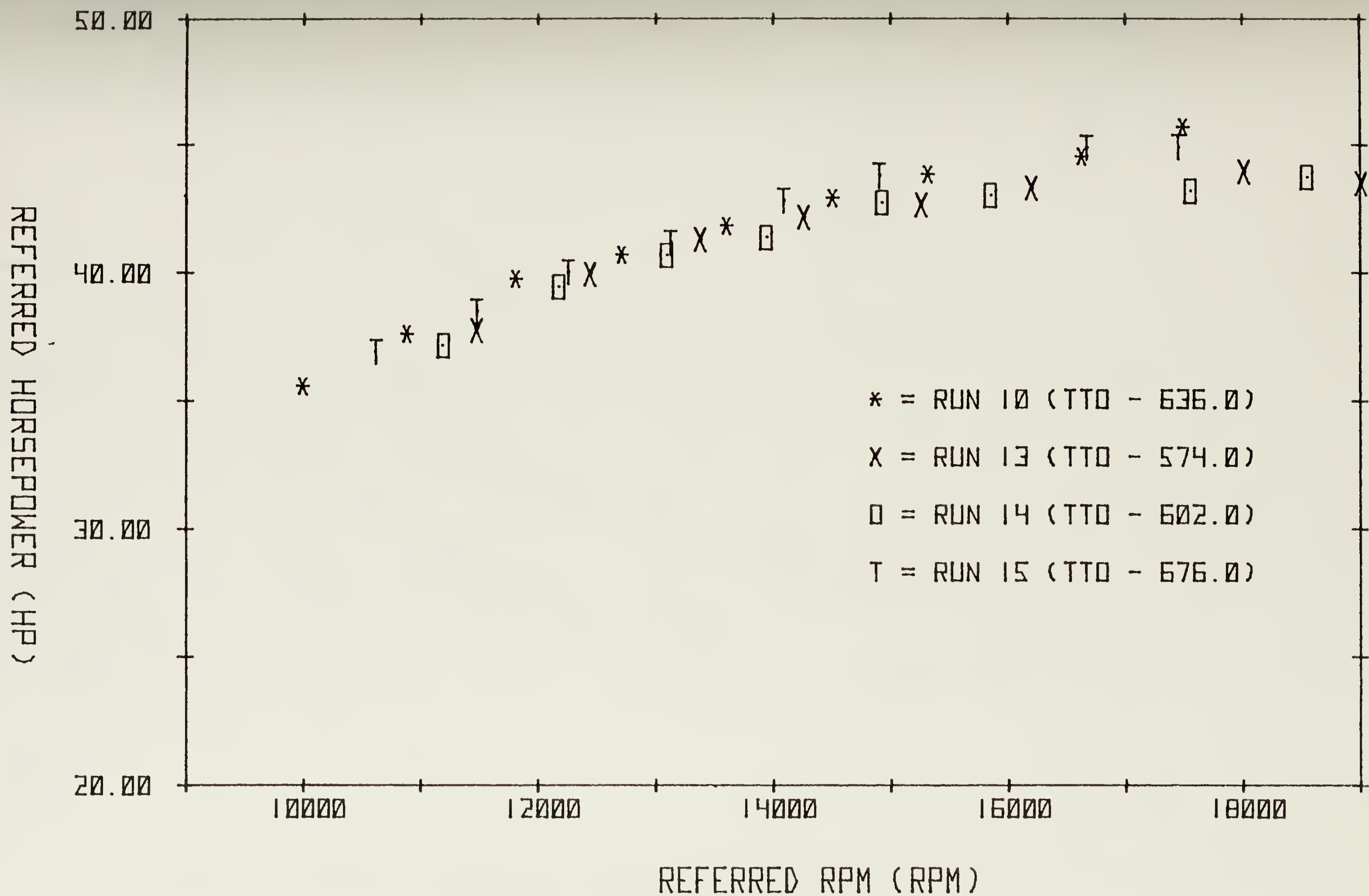


FIGURE 31. REFERRED HP vs. REFERRED RPM (PR=3.5, P_{t_o}=60 in Hg)

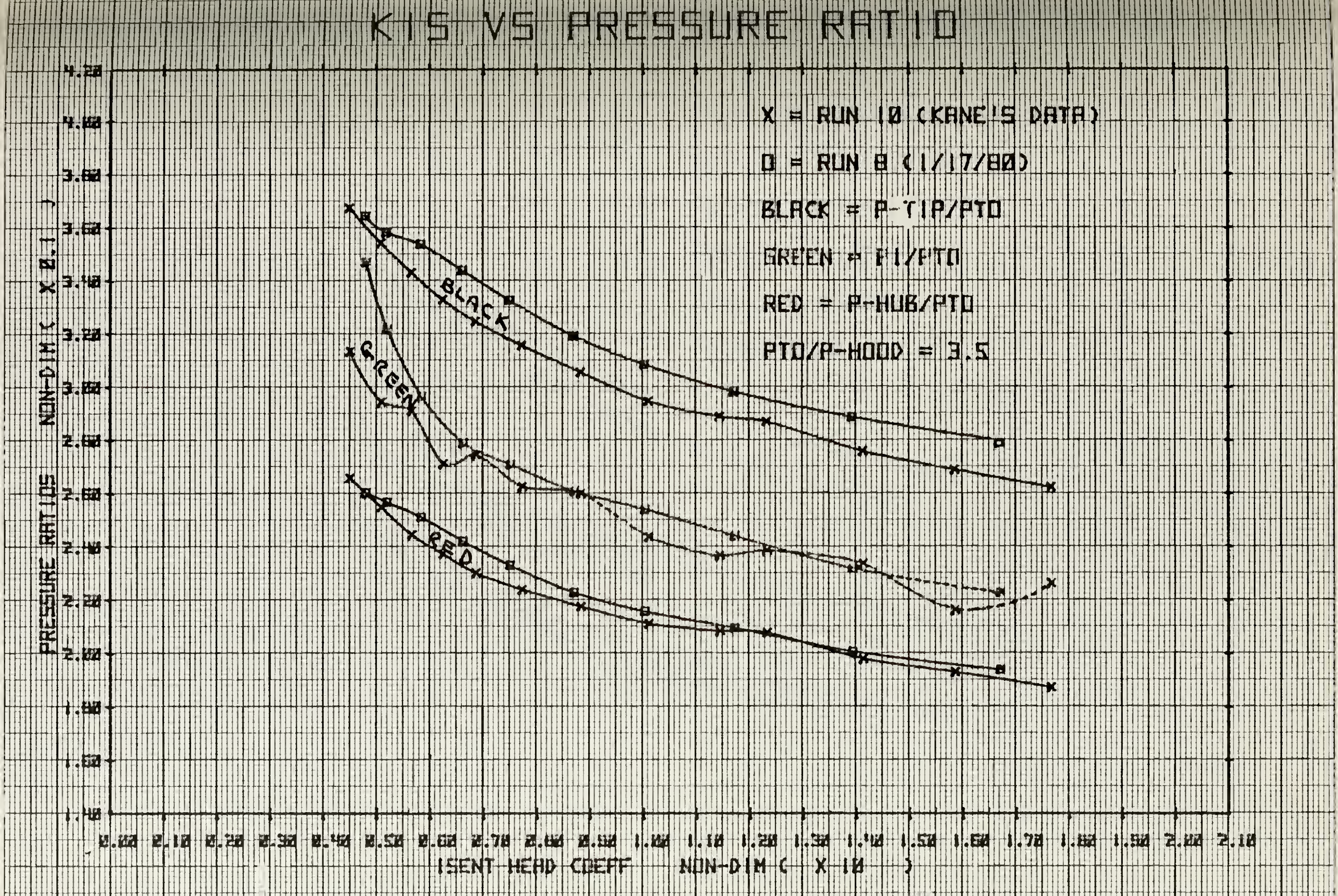


FIGURE 32. PRESSURE RATIO vs. ISENTROPIC HEAD COEFFICIENT
(PR=3.5, Pt_o=60 in Hg)

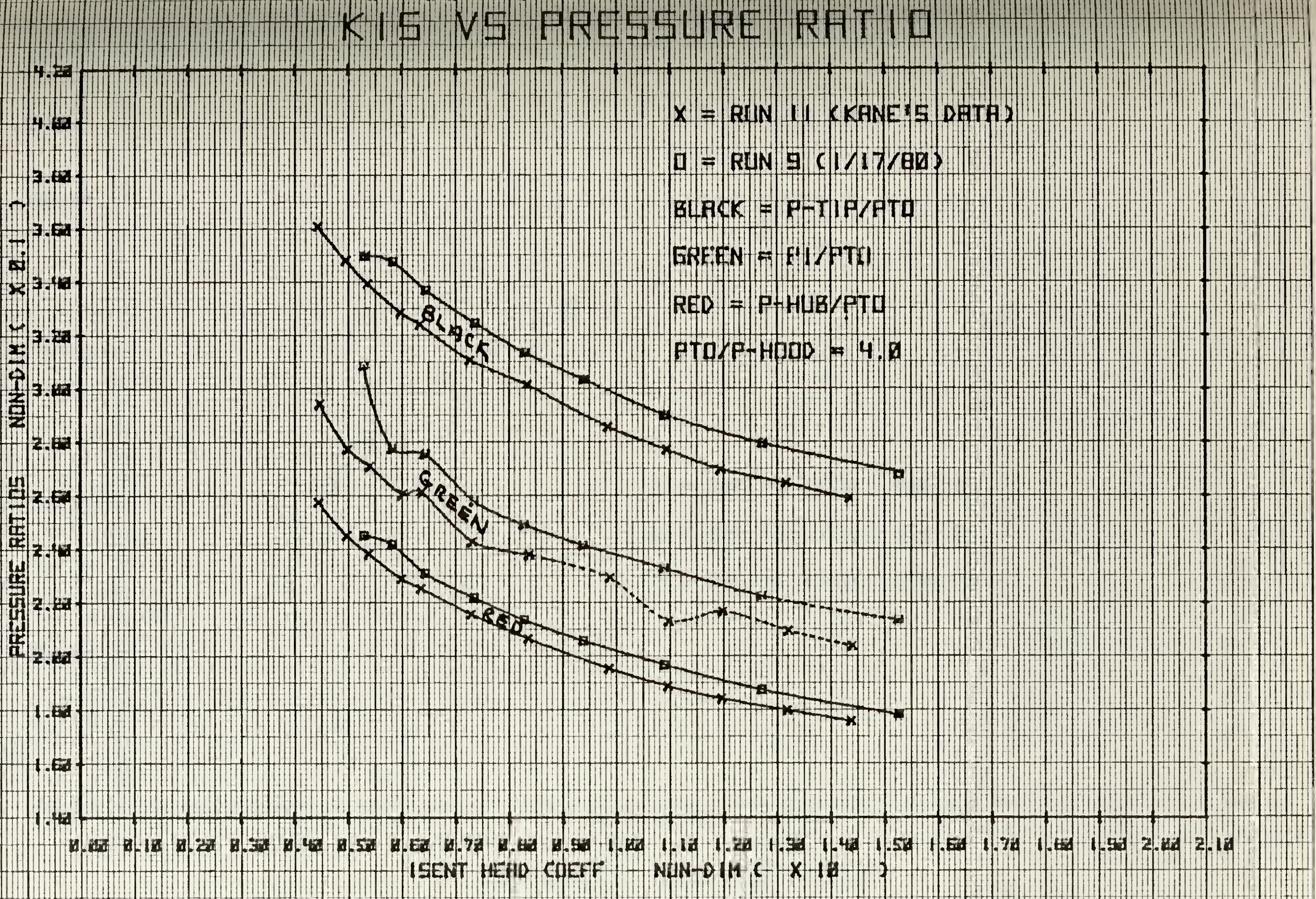


FIGURE 33. PRESSURE RATIO vs. ISENTROPIC HEAD COEFFICIENT
(PR=4.0, P_{t_o}=60 in Hg)

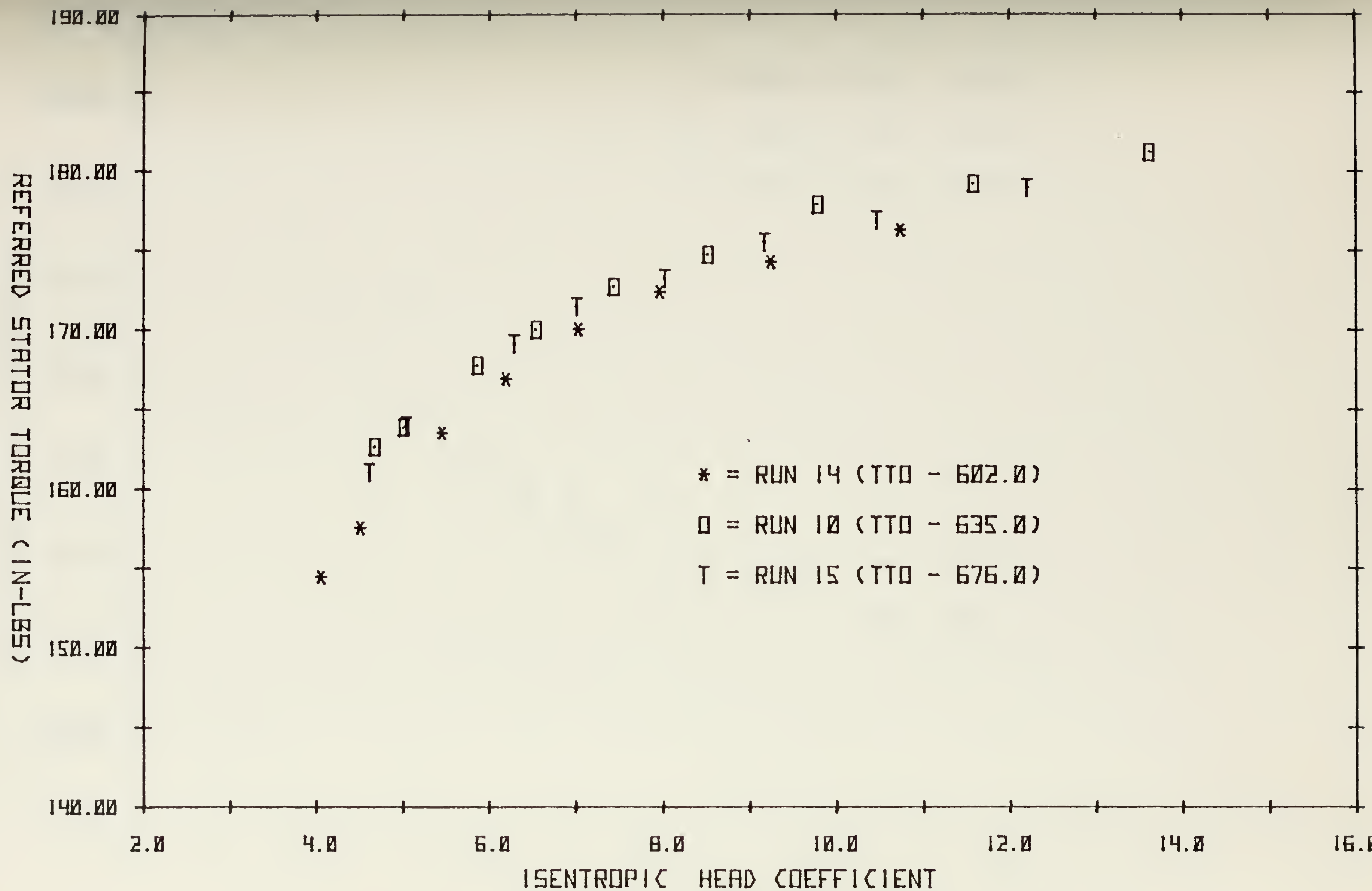


FIGURE 34. REFERRED STATOR TORQUE vs. ISENTROPIC HEAD COEFFICIENT
(PR=3.5, P_{t_o}=60 in Hg)

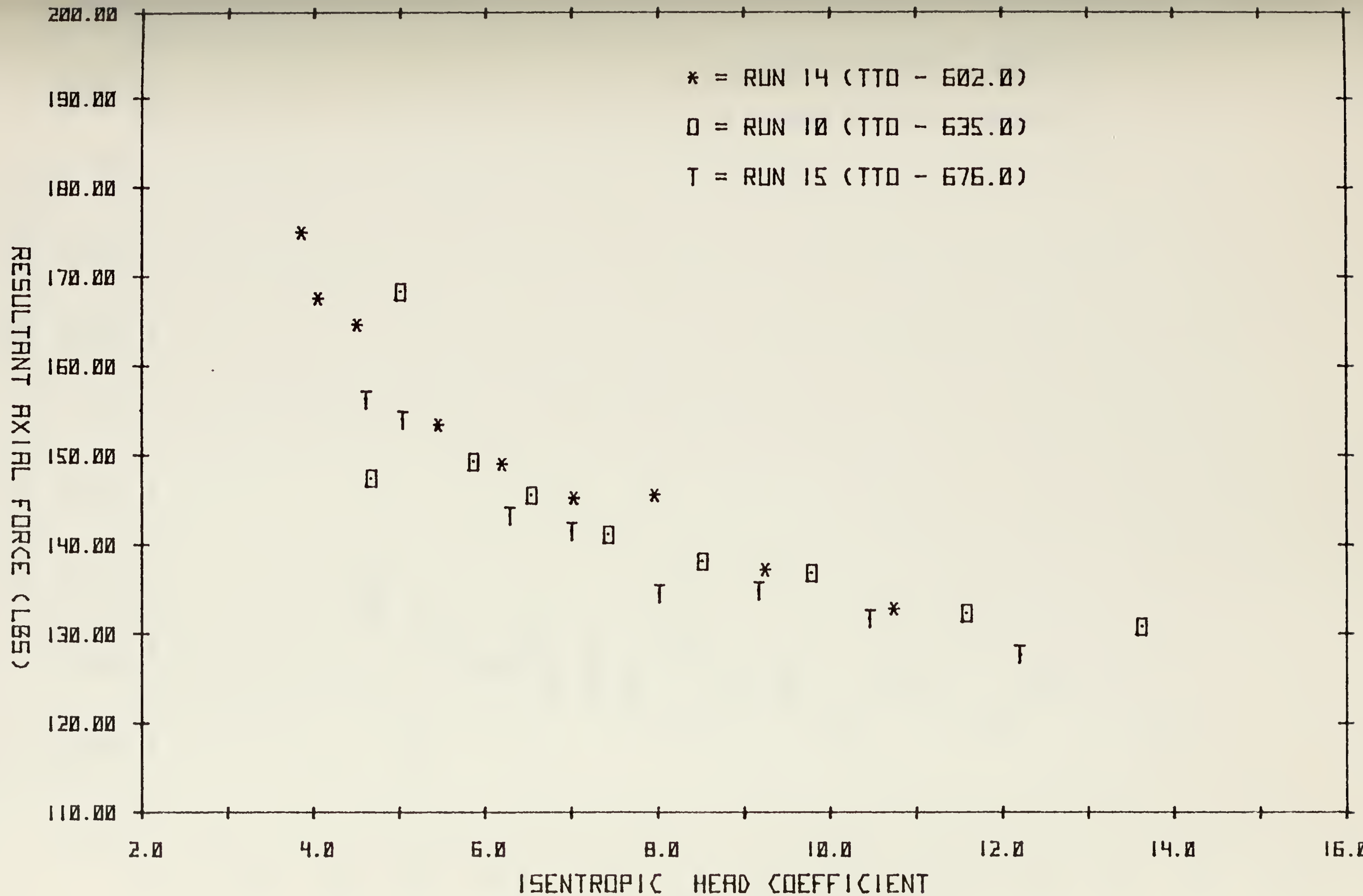


FIGURE 35. RESULTANT AXIAL FORCE vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, P_{t_o}=60 in Hg)

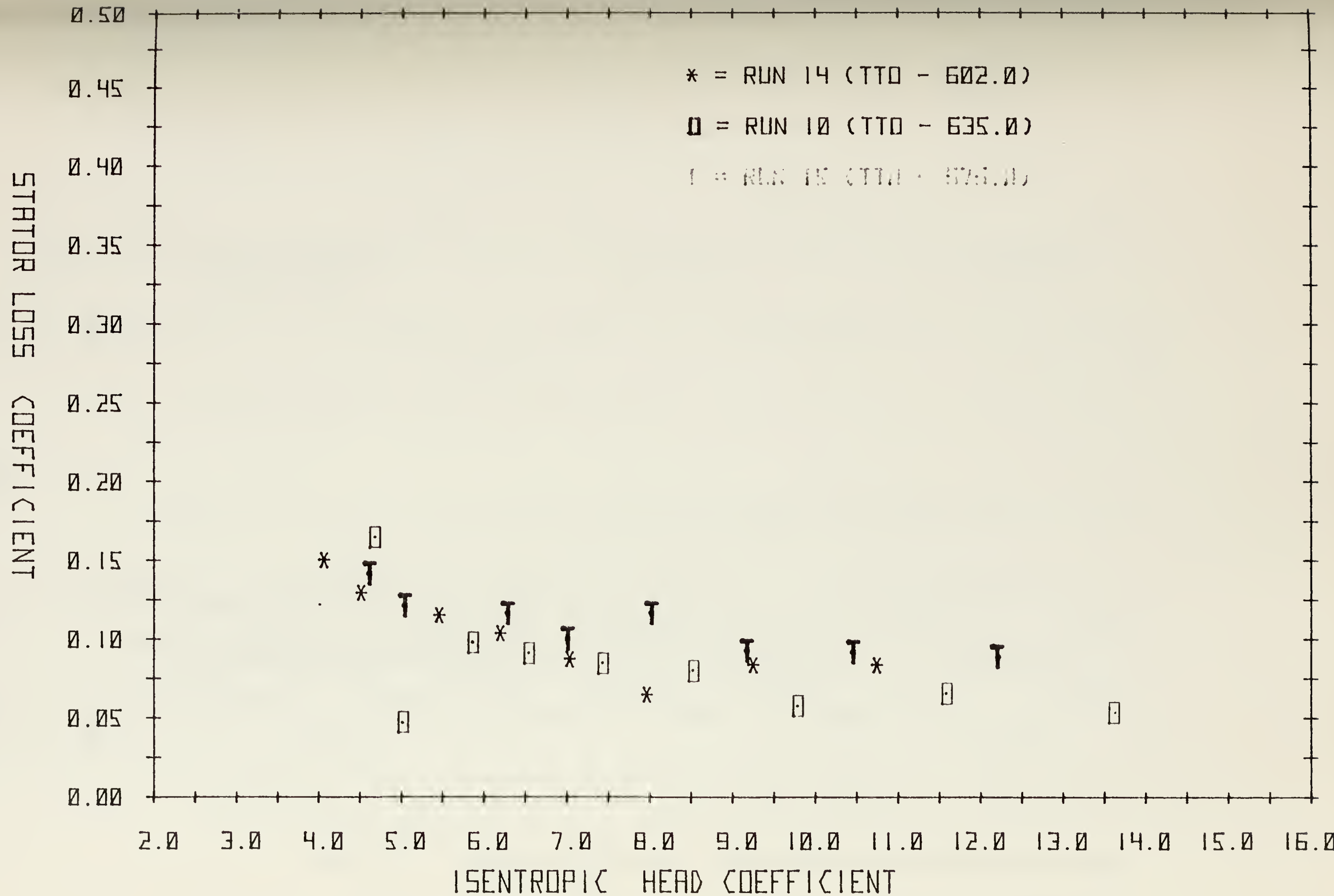


FIGURE 36. STATOR LOSS COEFFICIENT vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, Pt_o=60 in Hg)

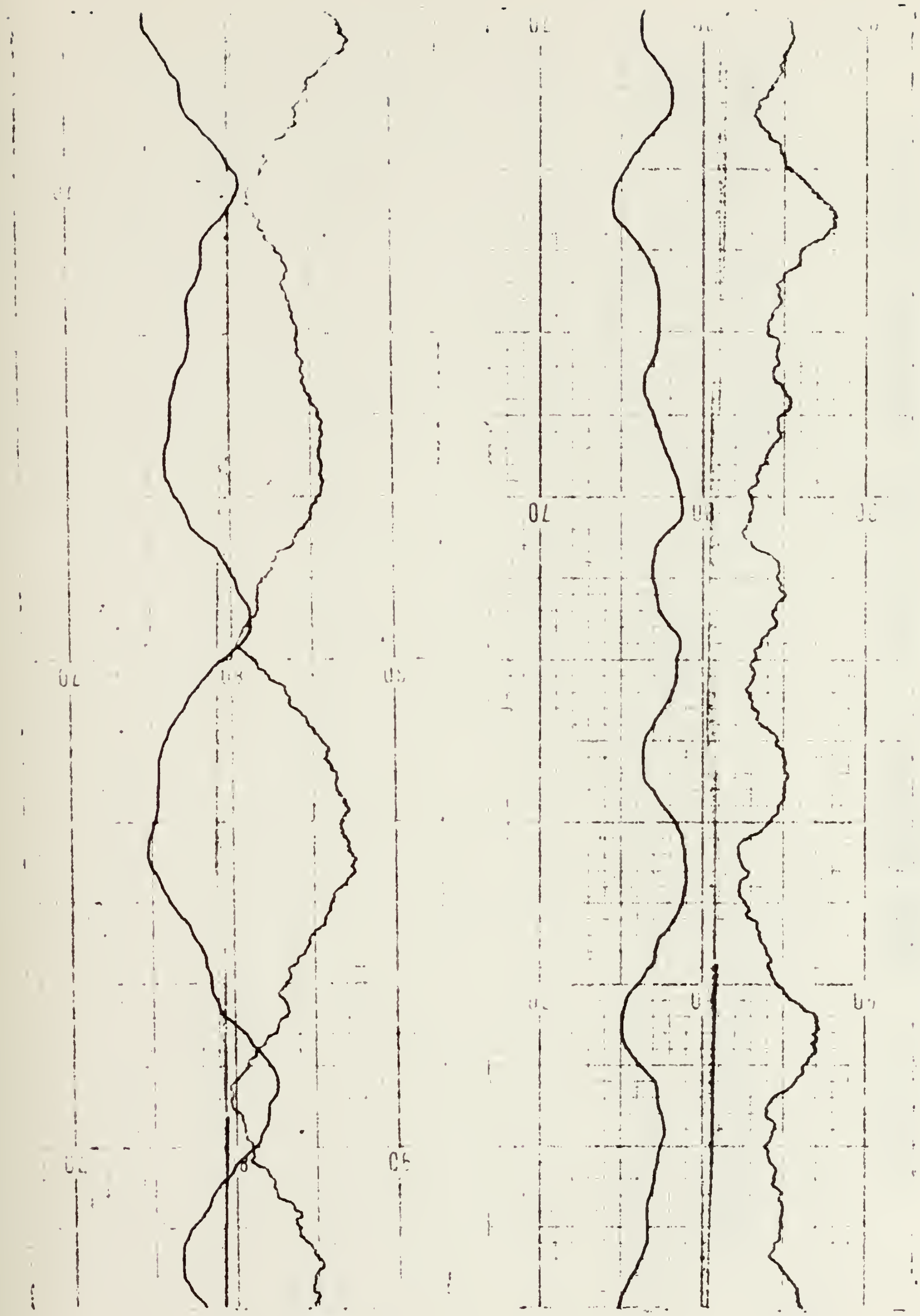


FIGURE 37. ANALOG RECORDING - AXIAL FORCE VARIATION WITH RPM (16000 RPM)

FIGURE 38. ANALOG RECORDING - CLOSURE FORCE VARIATIONS WITH RPM (16000 RPM)

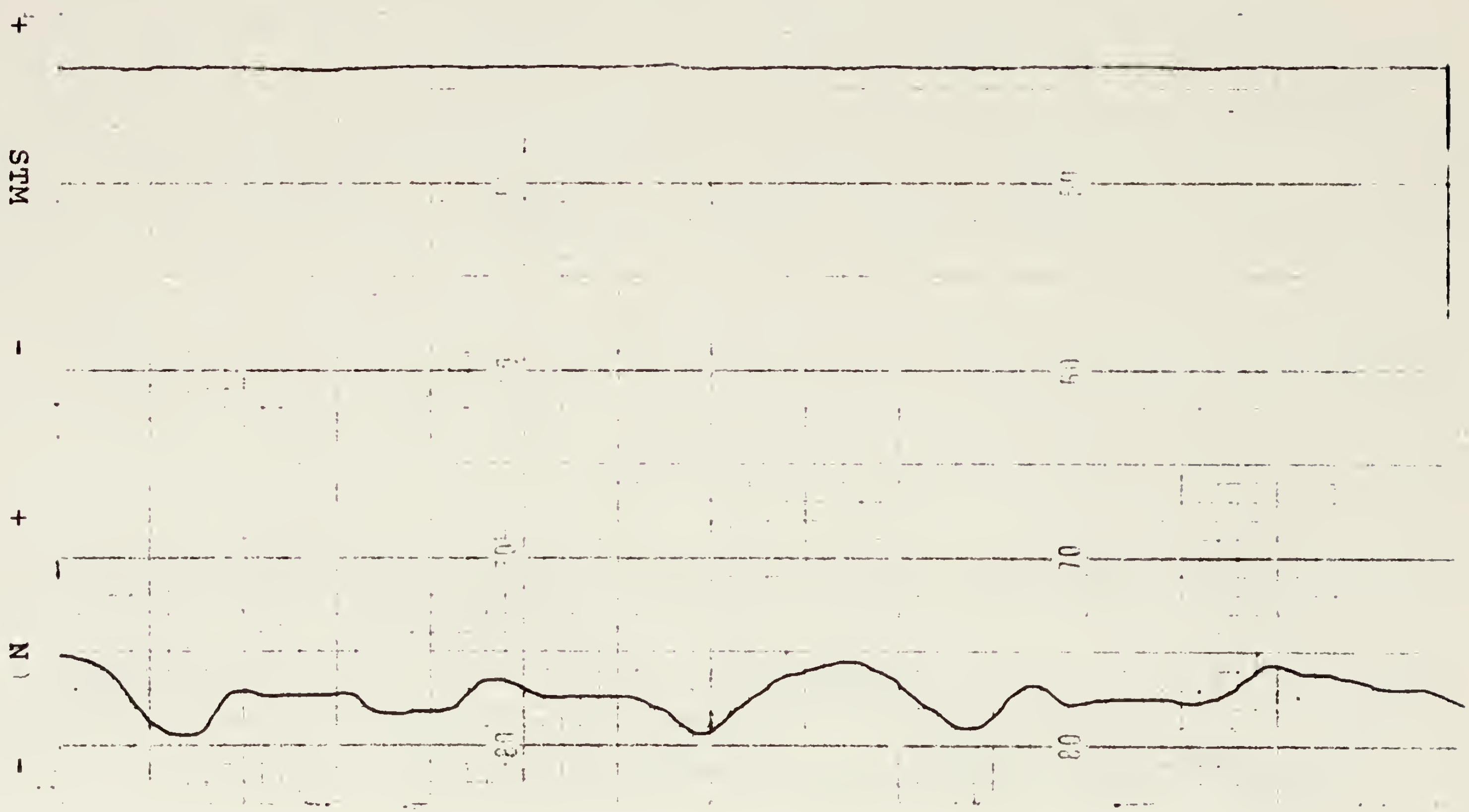


FIGURE 39. ANALOG RECORDING - STM VARIATIONS WITH RPM (16000 RPM)

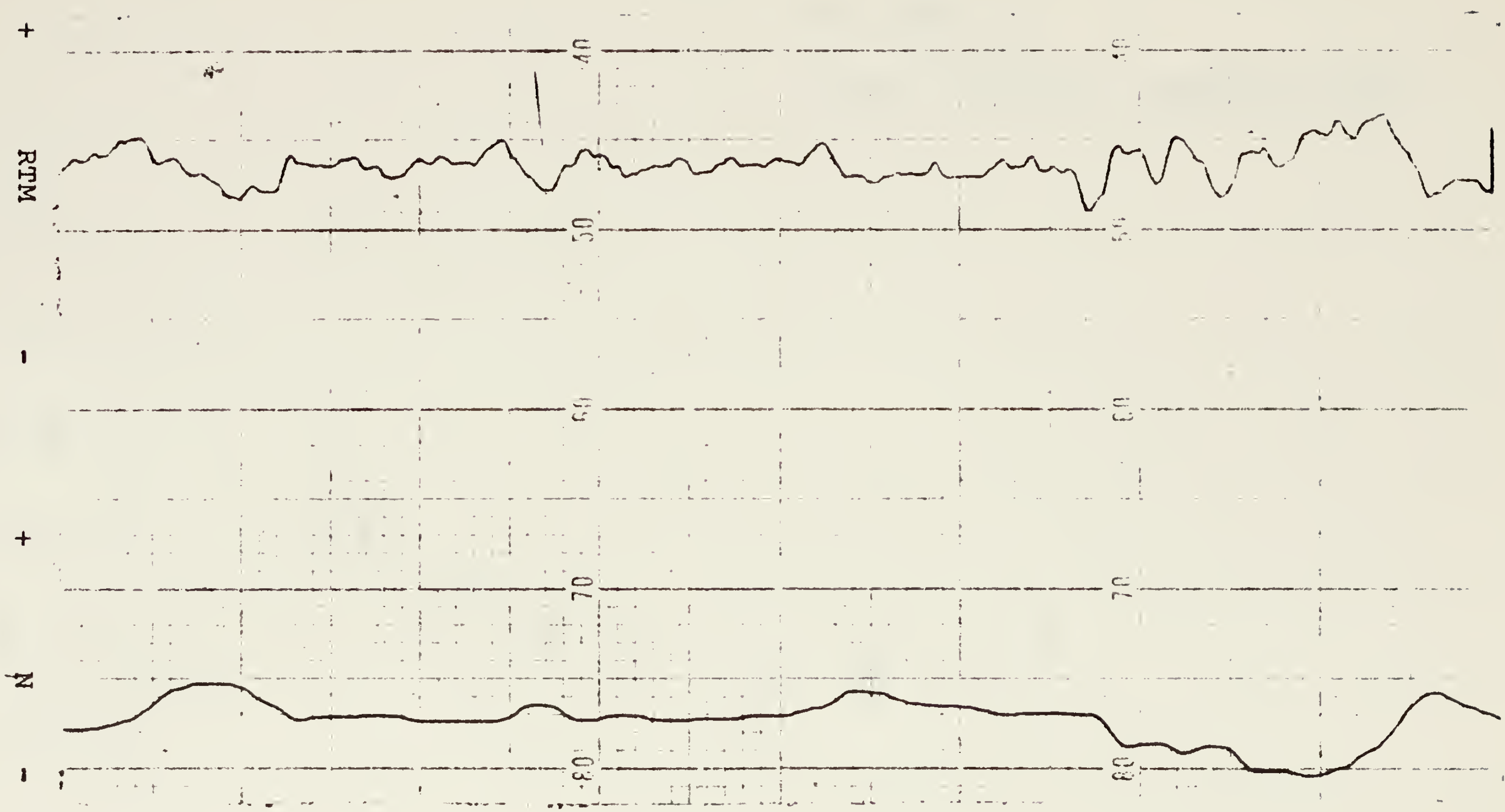


FIGURE 40. ANALOG RECORDING - RTM VARIATIONS WITH RPM (16000 RPM)

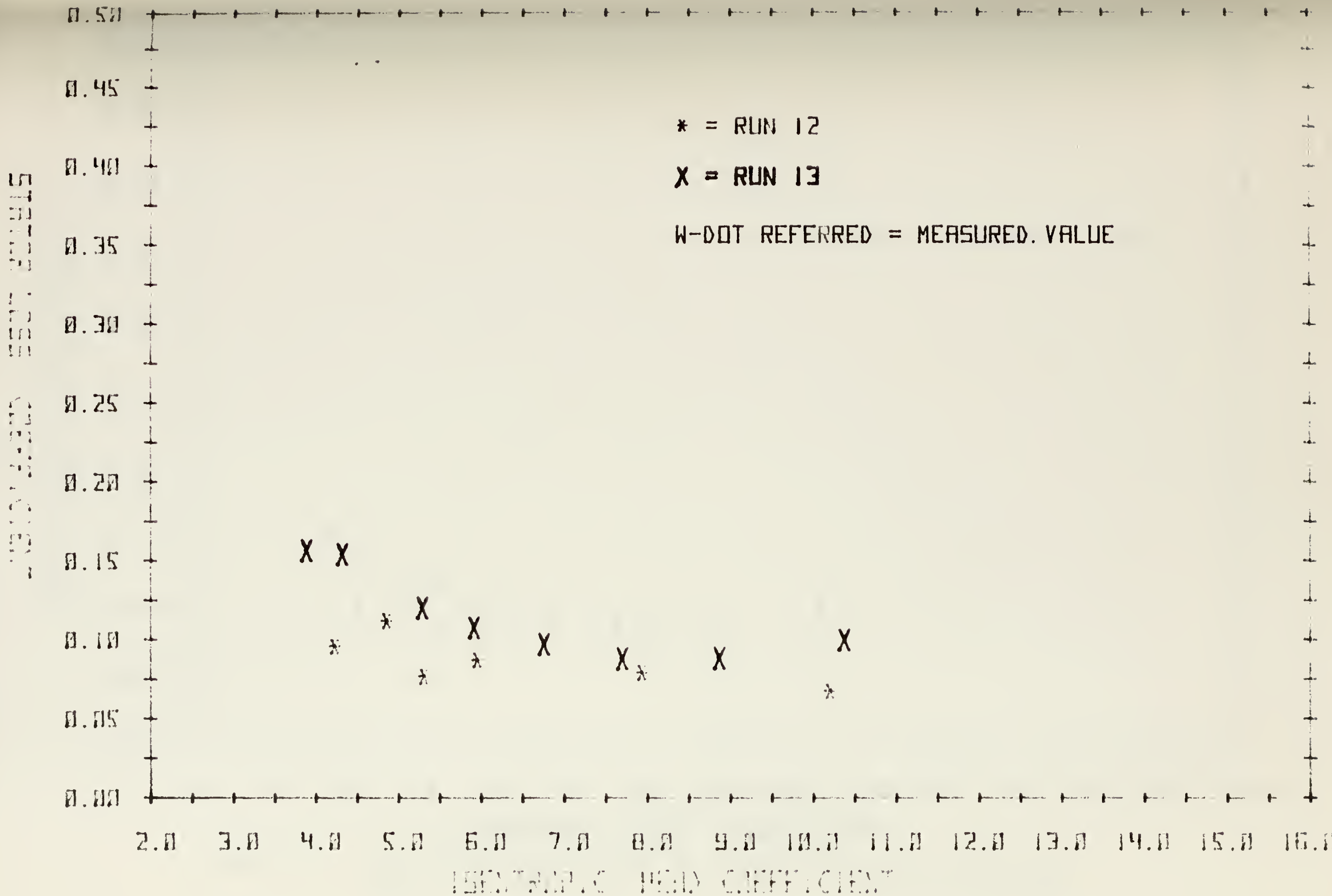


FIGURE 41. STATOR LOSS COEFFICIENT vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, P_{t_o}=60 in Hg, T_{t_o}=574° R, $\dot{W}_{ref}$ measured)

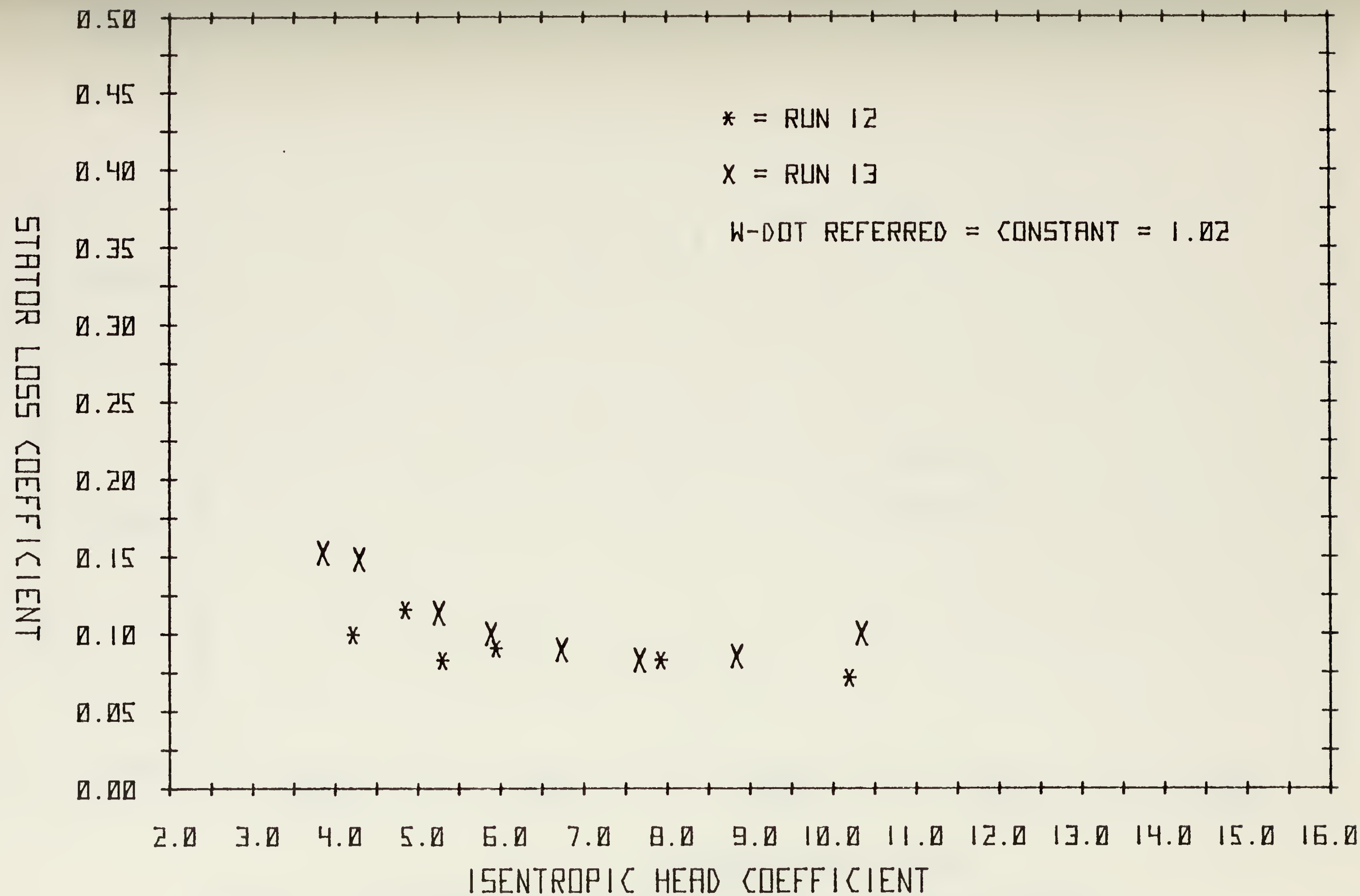


FIGURE 42. STATOR LOSS COEFFICIENT vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, P_{t_o}=60 in Hg, T_{t_o}=574° R, $\dot{W}_{ref}$=1.02=constant)

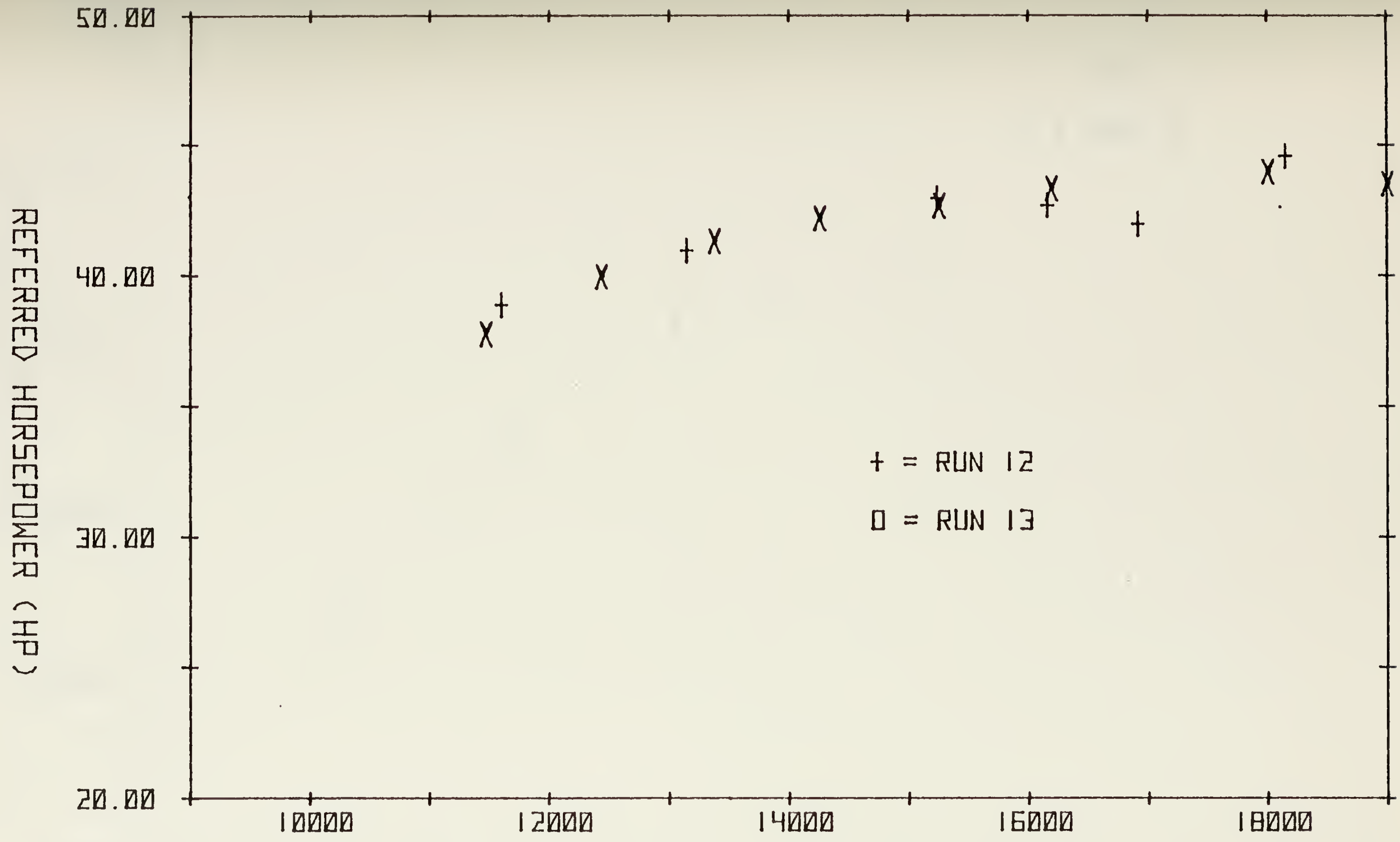


FIGURE 43. REFERRED HP vs. REFERRED N (PR=3.5, P_{t_o}=60 in Hg, T_{t_o}=574° R)

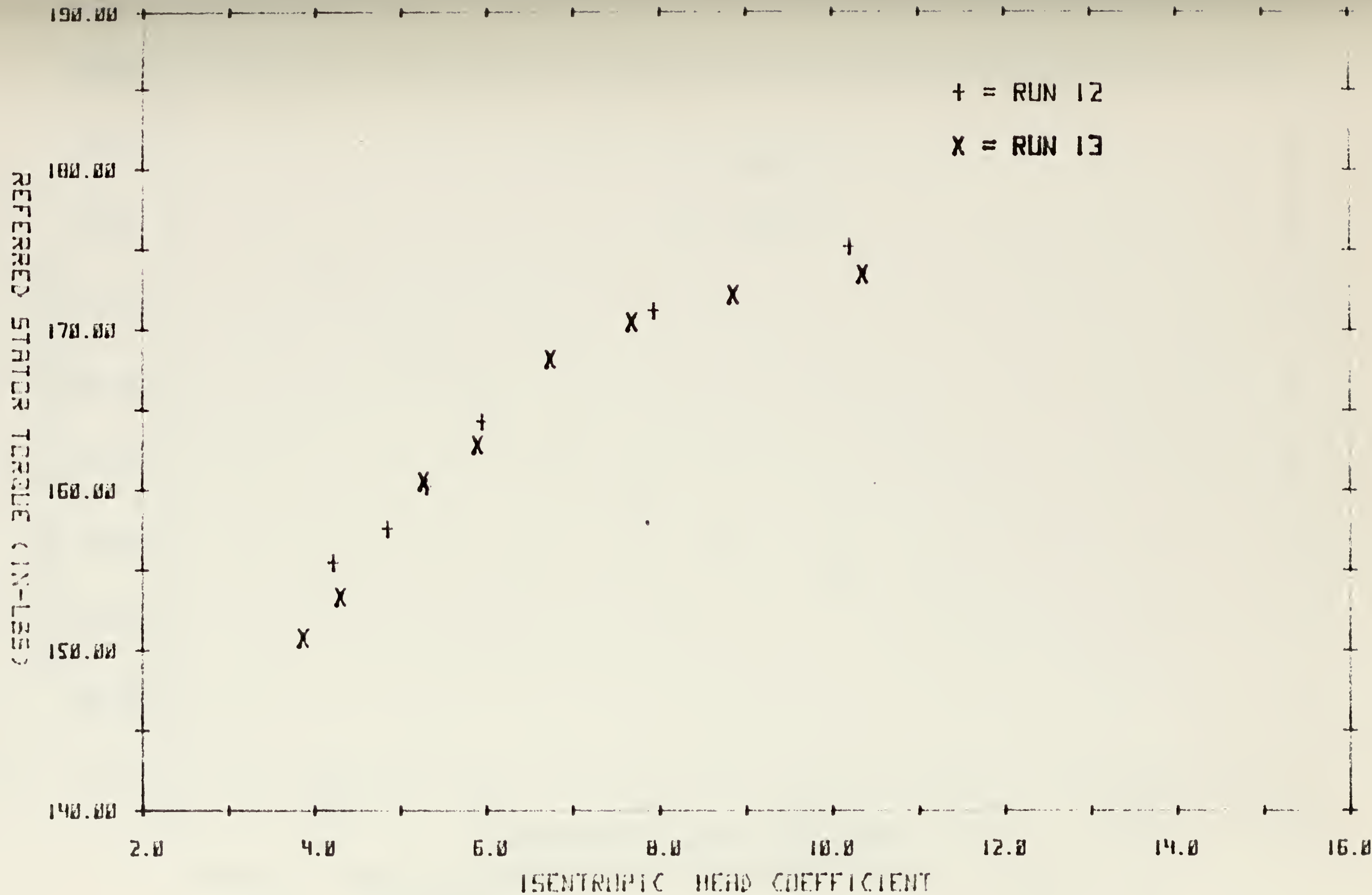


FIGURE 44. REFERRED STM vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, Pt_o=60 in Hg, T_{t_o}=574° R)

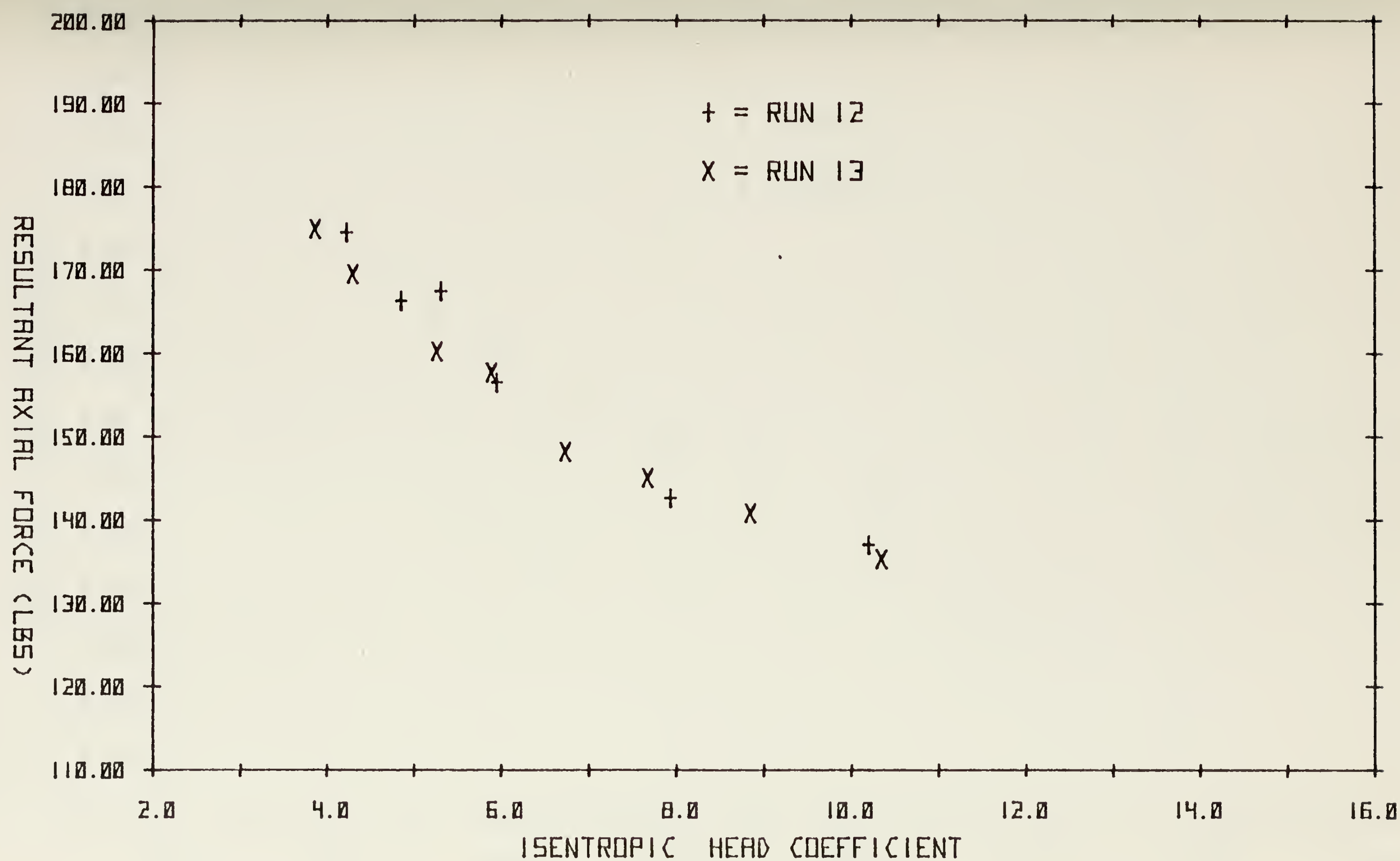


FIGURE 45. RAF vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, P_{t_o}=60 in Hg, T_{t_o}=574° R)

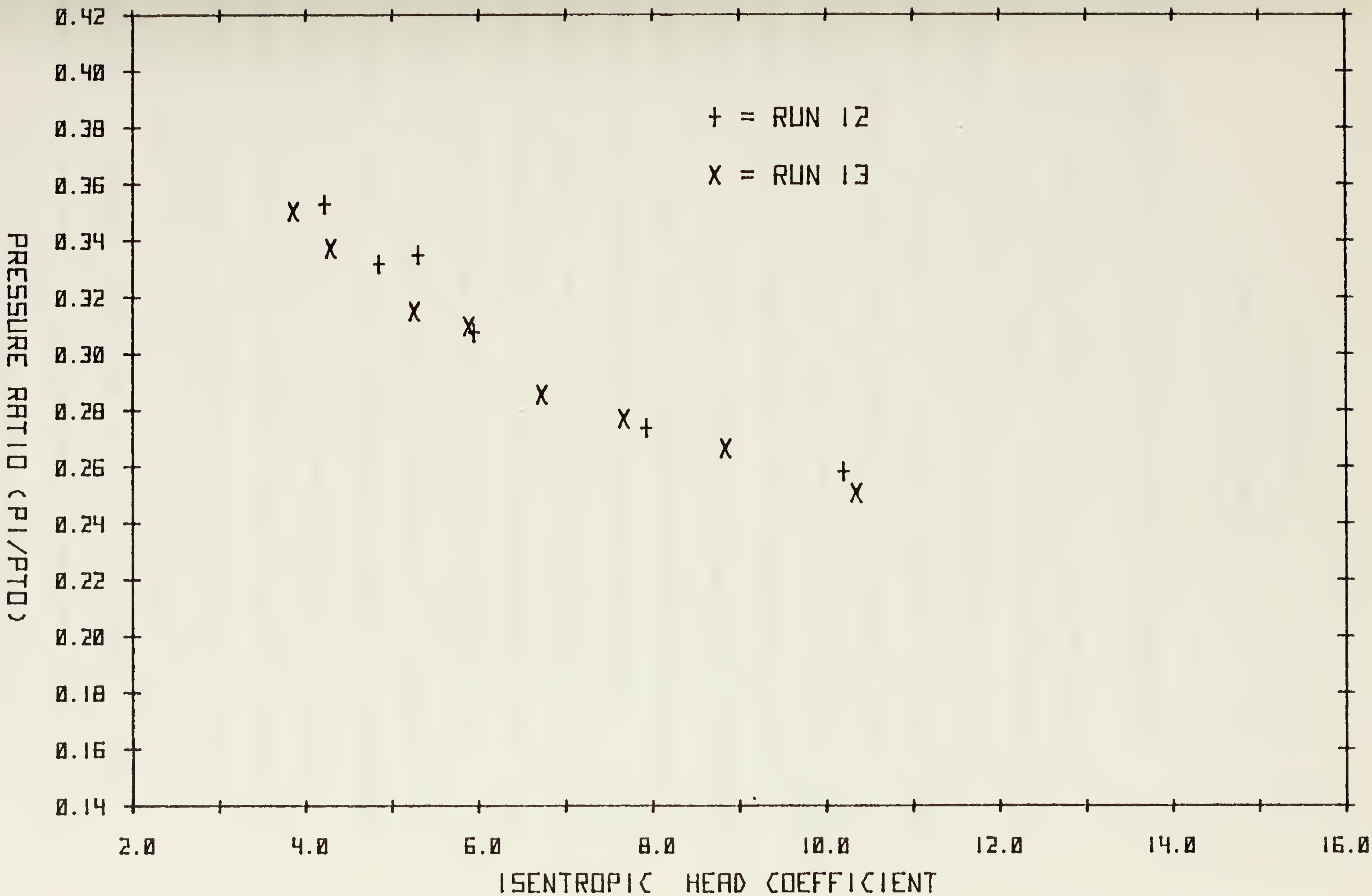


FIGURE 46. PRESSURE RATIO (P_1/P_{t_o}) vs. ISENTROPIC HEAD COEFFICIENT (PR=3.5, P_{t_o}=60 in Hg, T_{t_o}=574° R)

APPENDIX A

COMPUTER PROGRAMS

A.1. ACQUISITION, REDUCTION, AND BATCH PROCESSING PROGRAMS

The acquisition program used to acquire data in Ref. 1 was entitled "SCATTR". The name was changed to "SCAMOD" and the changes to the program are listed in Table A-1. Listings of the current acquisition and reduction programs are given in Tables A-II through A-IX. Programs TTR7, TTR8, and TTR11 are currently used to batch process raw data, reduced data, and uncertainty data, respectively. Listings of these programs are contained in Tables A-X through A-XII. Reduction programs were also modified, and the changes are listed in Table A-I. A new program, "UNCERT", was added to the reduction sequence to calculate uncertainty in the loss coefficients, RAF, and P_1/P_{t_o}. The formulas used in program "UNCERT" were obtained from the uncertainty development in Appendix C. A current listing of the reduction sequence is presented in Figure A-1. It will be noticed that the smoothing procedure using TTR1 and TTR9 has been deleted from the reduction sequence. (Examination of Figures 31 and 32 clearly showed that addition of the "slingers" to the waterbrake assembly resulted in much less noise in the calculated values of P_1, yielding a smoother variation of P_1/P_{t_o} than was seen in the data gathered in Ref. 1.)

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Line 590 in TTR2, which allowed setting W_{ref} = 1.02/lbm/sec = constant, was deleted since it had never been shown that the value should be constant at all test conditions. It will be noted that except for run 12, the W_{ref} for runs 10-15 was fairly constant at around 1.025 lbm/sec +/-.005.

The storage and batch processing programs (TTR6 and TTR8) were modified to print out engineering data and other parameters. Some consideration should be given in the future to expanding the storage array to include engineering and other data. There is room for more data elements per record than is presently stored. For example, the Labyrinth flow rate, flow nozzle pressure, temperature, and pressure differential should be stored.

It was necessary to "scratch" the acquisition program at the end of each data point in order to reduce the data just taken. It is recommended that the feasibility of merging the acquisition program with the reduction sequence be studied and undertaken if possible. The only limiting factor is the number of variables left from the reduction sequence which can be used in the acquisition program. A current list of the variables used in the reduction sequence only is listed in Figure A-2.

Table A-XIII contains a list of all new variables added to the reduction programs. A list of all plotting routines located on the TTR disc and variables plotted are listed in Table A-XIV.

The programs used to acquire the RPM samples, "RPMSUR", and to compare calculated and measured temperature drops, "TERRY7", are listed in Tables A-XV and A-XVI respectively. A list of all programs used for acquiring, modifying, or reducing the data presented in this report is given in Table A-XVII.

On runs 13 and 15, variations in the recorded voltage values for a pressure port measurement indicated the pressure line had developed a leak. Accordingly, the reduction program was altered to compensate for this situation. Table A-XX lists the pertinent runs and points applicable, pressure port, and action taken in the reduction sequence. The voltage values are listed in Tables XX and XXII for Runs 13 and 15, respectively.

A.2 FOURIER ANALYSIS PROGRAM

The program used for Fourier analyzing the RPM data was program "AUTOST" which is contained on tape and associated with the HP9845A computer system. The "DATA INPUT-TIME DOMAIN DATA" subprogram option was used and had to be modified as listed in Table A-XVIII. The data files containing the RPM data analyzed are recorded on the "TPL Library #1" tape in the NPS Turbomachinery Laboratory. The data file names are given in Table A-XVIII.

TABLE A-I

CHANGES IN THE ACQUISITION AND STORAGE PROGRAMS

PROGRAM	LINE	ACTION	COMMENTS
SCAMOD (see note 1)	100	Added array E(2)	Averages point 24 pressure
	110	added	Enters run #, day, month, year
	160	added	Takes multiple points without restarting program
	180	added	Loops program for multiple points
	190	added	assigns point number for data run
	210/240	added	Assigns point number when auto-storage <u>not</u> selected
	350 and 1710-2280 (see note 2)		Records 46 pressures on scanivalve system
	860-990	delete temperature averaging	extraneous
	870-1690	Recorded channel numbers changed (see Appendix B)	Changed channel setup

TABLE A-1 (Cont'd)

	1050 and 2290-2960	Port 24 averaged	Averaging sequence
TTRIB	30	added N(20)	"UNCERT" program storage array
	40-50	added counter "D"	Record # for storage of "UNCERT" data
	443	modified	channel number assignments
	451	modified	channel number assignments
	632-634	added	turbine outlet temperature
	752-758	added	pressure conversion to in. Hg
	770-1080	modified	scaling factors assignment
	1100-1120	modified	scaling factors assignment
	1060	changed	more stable port
	1090,1150, 1160,1180, 1190	modified	channel reassignment
	1110	changed	averaged channel used
TTR2	590	deleted	eliminates constant $\dot{W}_{ref}$
	1127	added	facilitates multiple single point reduction without smoothing
TTR3	580	modified	chains to "UNCERT" for uncertainty calculations
UNCERT	All	added	calculates uncertainties

TTR5	60	modified	channels reassignment
	85	added	prints T_{t_o}
	92,96	added	prints calculated $\dot{W}$, $\dot{W}_{ref}$
	105	added	turbine stator nozzle Reynolds Number printout
	534-538	added	P_{T1P}/P_{t_o}, P_1/P_{t_o}, and P_{HUB}/P_{t_o} printout
TTR6	470-510	modified	different channels used
	520-562	added	stores 19 other data parameters (see note 3)
	690-692	added	chains to TTRIB for multiple point reduction with no smoothing
TTR7	270-330, 480-780	modified	channels reassigned
	348	added	program loop more efficient
	410	added	"Table" format
TTR8	Completely renumbered and reformatted to conform with 19 additional parameters stored in TTR6.		
TTR11	All	added	Batch processes the "UNCERT" data

TABLE A-1 (Cont'd)

Note 1: Due to the extensive nature of the modifications to "SCATTR" (see Ref. 1), the program was changed to "SCAMOD" and renumbered. Major additions to the program are listed in the table.

Note 2: These lines replaced lines 110-210 of "SCATTR" program (see Ref. 1) due to replacement of the paper tape system with on-line data acquisition.

Note 3: The nineteen additional stored items, beginning with line 520, are:

Line	Program Variable	Parameter
520	Z9	$\dot{W}$
525	V9	$\dot{W}_{ref}$
530	Q8	Re No. (Stator)
532	H1	Horsepower
534	M5	Rotor Torque
536	M6	Stator Torque
538	F4	Stator Axial Force
540	F5	Closure Plate Force
542	R2	Resultant Force on stator
544	Q1	P_{t_o}
546	T2	T_{t_o}
548	Q3	Hood Pressure

TABLE A-1 (Cont'd)

550	Q4	Static pressure at stator tap "Tip #3"
552	SØ	Stator Exit Pressure
554	R8	Static pressure at stator tap "HUB #3"
556	Q4/Q1	P_{TIP}/P_{t_o}
558	P2	P_1/P_{t_o}
560	R8/Q1	P_{HUB}/P_{t_o}
562	T2-T1	Temperature difference across the stage

TABLE A-II

PROGRAM "SCAMOD"

```
10 REM      PROGRAM NAME: SCAMOD
20 REM      PROGRAM DISC: TURBINE TEST RIG PL-002
30 PRINT "CHECK APPROPRIATE FILENAME, LINES 500,610, AND VALUE OF K, LINE"
40 PRINT "1030 TO ENSURE YOU HAVE THE NUMBER OF SCANS DESIRED, CONTINUE 100"
50 PRINT
60 PRINT
70 PRINT
80 PRINT
90 STOP
100 DIM C$[27],A$[48],D$[30,40],B$[20],E[2]
110 DISP "ENTER RUN #,DATE (MONTH, DAY, YEAR)";
120 INPUT R1,M0,D0,Y1
130 DISP "AUTO STORAGE? YES=1, NO=0";
140 INPUT Z
150 IF Z=0 THEN 210
160 DISP "ENTER FIRST RECORD # THIS RUN,TOTAL # OF POINTS DESIRED THIS RUN";
170 INPUT E1,E2
180 FOR Q=1 TO E2
190 P1=Q
200 GOTO 250
210 P1=0
220 DISP "ENTER NEXT RECORD # ON DATA FILE";
230 INPUT E1
240 P1=P1+1
250 MAT A=ZER
260 MAT C=ZER
270 MAT D=ZER
280 PRINT
290 PRINT
300 PRINT
310 PRINT
320 WRITE (15,330)R1,P1,M0,D0,Y1,"    TURBINE C"
330 FORMAT "RUN",F4.0,1X,"PT.",F4.0,2X,"DATE",F4.0,1X,F4.0,1X,F4.0,F4.0
340 GOSUB 760
350 GOSUB 1710
```

TABLE A-II (Cont'd)

```
360 REM************DATA CORRECTIONS*****************************************
370 DISP "CORRECTIONS TO DATA?-YES=1,NO=0";
380 INPUT G1
390 IF G1=0 THEN 490
400 DISP "PRESS PRT ALL KEY FOR RECORD.";
410 WAIT 7000
420 DISP "ENTER CORRECTION AS MATRIX ELEMENT";
430 WAIT 7000
440 DISP "ENTER CORRECT VALUE=?; EXEC.,CONT.,EXEC.";
450 STOP
460 DISP "ANY MORE CORRECTIONS? YES=1,NO=0";
470 INPUT G1
480 IF G1=1 THEN 440
490 REM**********STORE RAW DATA IN FILES RAWDAT******************************
500 FILES RAWDAT
510 DISP "STORE DATA? ENTER YES=1,NO=0";
520 INPUT G1
530 IF G1=0 THEN 700
540 C[10]=R1
550 C[11]=P1
560 C[12]=M0
570 C[13]=D0
580 C[14]=Y1
590 MAT PRINT # 1,E1;C,A
600 PRINT
610 PRINT "THE RAW DAT IS STORED IN RAWDAT RECORD # "E1
620 PRINT
630 PRINT
640 IF Z=0 THEN 220
650 E1=E1+1
660 DISP "PRESS CONT WHEN READY FOR NEXT PT";
670 STOP
680 NEXT Q
690 GOTO 740
700 PRINT "THIS DATA WAS NOT STORED"
```

TABLE A-II (Cont'd)

```
710 DISP "DO YOU WISH TO CONTINUE; YES=1,NO=0";
720 INPUT G1
730 IF G1=1 THEN 100
740 STOP
750 END
760 REM**********FUSCAN**********W.J.KANE**********12/1/78
770 REM
780 REM     DISCRIPTION: THIS SUBROUTINE IS DESIGNED TO RECORD THE NINE
790 REM                  NON-PRESSURE CHANNELS CONNECTED WITH THE TURBINE
800 REM                  TEST RIG DATA GATHERING SYSTEM
810 CMD "?D"
820 FORMAT 4B
830 FORMAT 3B
840 FORMAT F3.0
850 OUTPUT (13,820)256,20,768,512;
860 REM*****BEGIN SCAN**********************************************************
870 B$="F1R7M3T3"
880 CMD "?D#",B$
890 B$="PF4G5S0"
900 CMD "?D%",B$
910 FOR I=0 TO 6
920 CMD "?D("
930 OUTPUT (13,840)I
940 CMD "?D#"
950 OUTPUT (13,830)256,8,512
960 CMD "?C$"
970 ENTER (13,*)A0
980 C[I+1]=A0
990 NEXT I
1000 CMD "?D(","C"
1010 REM*****THE VALUE OF K ENTERED NEXT REPRESENTS THE NUMBER OF SCANS
1020 REM*****USED IN AVERAGING THE NON-PRESSURE VALUES
1030 K=30
1040 FOR J=1 TO K
1050 GOSUB 2290
```

```
1060 D[J,17]=E[1]
1070 WRITE (13,820)256,20,768,512;
1080 B$="F1R7M3T3"
1090 CMD "?D#",B$
1100 B$="PF4G5S0"
1110 CMD "?D%",B$
1120 OUTPUT (13,820)256,8,768,512;
1130 FOR I=16 TO 27
1140 IF I=17 THEN 1290
1150 IF I=22 THEN 1300
1160 CMD "?D!"
1170 OUTPUT (13,840)I
1180 IF I=16 THEN 1220
1190 CMD "?D#"
1200 OUTPUT (13,820)256,8,768,512;
1210 GOTO 1250
1220 CMD "?D%","T"
1230 CMD "?E$"
1240 GOTO 1260
1250 CMD "?C$"
1260 ENTER (13,*)A0
1270 D[J,I]=A0
1280 GOTO 1300
1290 I=I+2
1300 NEXT I
1310 CMD "?D!","C"
1320 NEXT J
1330 CMD "?D!","C"
1340 PRINT
1350 PRINT "THE FOLLOWING ARE THE NON-S/V CHANNEL READINGS"
1360 PRINT
1370 PRINT
1380 PRINT N;"SCANS COMPLETED"
1390 PRINT
1400 FOR J=16 TO 27
```

TABLE A-II (Cont'd)

```
1410 IF J=18 THEN 1510
1420 IF J=22 THEN 1510
1430 S1=0
1440 FOR I=1 TO K
1450 S1=S1+D[I,J]
1460 NEXT I
1470 IF J#16 THEN 1500
1480 C[16]=((S1/K)*2)
1490 GOTO 1510
1500 C[J]=S1/K
1510 NEXT J
1520 WRITE (15,1540)C[16]
1530 FORMAT "CHANNEL",F3.0,"=",F10.6
1540 FORMAT "RPM =",F10.0,/
1550 FOR J=0 TO 27
1560 IF J<7 THEN 1600
1570 IF J>19 THEN 1620
1580 J=J+12
1590 GOTO 1640
1600 WRITE (15,1530)J,C[J+1]
1610 GOTO 1640
1620 IF J=22 THEN 1640
1630 WRITE (15,1530)J,C[J]
1640 NEXT J
1650 WRITE (15,1660)
1660 FORMAT /,"S/V=1",/,/,"PORT",4X,"PRESSURE"
1670 WRITE (15,1680)C[17]
1680 FORMAT 1X,"24",1X,F12.6
1690 RETURN
1700 END
1710 REM**********HAMMOD**********T.P.EARGLE*****7/17/79************************
1720 REM      DATE:    NOV 79
1730 REM
1740 FORMAT E
1750 FORMAT 2B
```

TABLE A-II (Cont'd)

```
1760 FORMAT 4B
1770 FORMAT F3.0
1780 WRITE (13,1760)256,20,768,512;
1790 CMD "?D#","F1R7M3A1H1T3"
1800 V=1
1810 CMD "?D'"
1820 WRITE (13,1740)V;
1830 WRITE (15,1840)V
1840 FORMAT "SCANIVALVE #",F3.0,/,/," PORT",8X,"VOLTAGE",8X,"PORT",8X,"VOLTAGE"
1850 FOR B=1 TO 48
1860 GOSUB 2020
1870 CMD "?D!"
1880 WRITE (13,1770)V+9
1890 CMD "?D#","T3"
1900 CMD "?C$"
1910 ENTER (13,*)V0
1920 A[B]=V0
1930 CMD "?D!","C"
1940 NEXT B
1950 FOR B=1 TO 48 STEP 2
1960 WRITE (15,1970)B,A[B],B+1,A[B+1]
1970 FORMAT 1X,F3.0,4X,F12.6,9X,F3.0,4X,F12.6
1980 NEXT B
1990 RETURN
2000 STOP
2010 REM  SUBROUTINE "POSIT"
2020 GOSUB 2200
2030 D=B-P
2040 CMD "?D!"
2050 IF D<0 THEN 2080
2060 IF D>0 THEN 2130
2070 RETURN
2080 REM    HOME S/V
2090 WRITE (13,1770)V+4
2100 WRITE (13,*)"C"
```

```
2110 WAIT 4000
2120 GOTO 2020
2130 REM      ADVANCE S/V
2140 FOR I=1 TO D
2150 WRITE (13,1770)V-1
2160 WRITE (13,*)"C"
2170 WAIT 50
2180 NEXT I
2190 GOTO 2020
2200 REM      READ S/V ADDRESS
2210 CMD "?G$"
2220 P0=RBYTE13
2230 L=BIAND(P0,15)
2240 T=ROT(P0,4)
2250 M=BIAND(T,7)
2260 P=10*M+L
2270 WRITE (13,1750)256,95;
2280 RETURN
2290 REM      FILE NAME: "HAM2"
2300 REM      DISC LABEL: PL-006 (MCGUIRE)
2310 REM
2320 REM      DESCRIPTION:
2330 REM        THIS PROGRAM PERFORMS SEQUENTIAL SCANNING
2340 REM      OF SCANIVALVE 'V' BETWEEN PORT ADDRESSES SPECIFIED.
2350 REM
2360 REM      VARIABLES:
2370 REM        V  = DESIRED S/V
2380 REM        A1 = LOW PORT
2390 REM        A2 = HIGH PORT
2400 REM        P  = PRESENT S/V PORT
2410 REM        S  = STEP SIZE
2420 REM
2430 REM      AUTHOR: R.N. GEOPFARTH,LT USN
2440 REM      DATE:   FEB 79
2450 REM
```

TABLE A-II (Cont'd)

```
2460 FORMAT B
2470 FORMAT 2B
2480 FORMAT 4B
2490 FORMAT F3.0
2500 WRITE (13,2480)256,20,768,512;
2510 CMD "?D#","F1R7M3A1H1T3"
2520 V=1
2530 T1=1
2540 S=1
2550 CMD "?D'"
2560 WRITE (13,2460)V;
2570 FOR A=24 TO 24
2580 GOSUB 2700
2590 CMD "?D!"
2600 WRITE (13,2490)V+9
2610 CMD "?D#","T3"
2620 CMD "?C$"
2630 ENTER (13,*)V0
2640 E[T1]=V0
2650 CMD "?D!","C"
2660 NEXT A
2670 RETURN
2680 STOP
2690 REM  SUBROUTINE "POSIT"
2700 GOSUB 2880
2710 D=A-P
2720 CMD "?D!"
2730 IF D<0 THEN 2760
2740 IF D>0 THEN 2810
2750 RETURN
2760 REM    HOME S/V
2770 WRITE (13,2490)V+4
2780 WRITE (13,*)"C"
2790 WAIT 4000
2800 GOTO 2700
```

TABLE A-II (Cont'd)

```
2810 REM      ADVANCE S/V
2820 FOR I=1 TO D STEP S
2830 WRITE (13,2490)V-1
2840 WRITE (13,*)"C"
2850 WAIT 50
2860 NEXT I
2870 GOTO 2700
2880 REM      READ S/V ADDRESS
2890 CMD "?G$"
2900 P0=RBYTE13
2910 L=BIAND(P0,15)
2920 T=ROT(P0,4)
2930 M=BIAND(T,7)
2940 P=10*M+L
2950 WRITE (13,2470)256,95;
2960 RETURN
```

TABLE A-III

PROGRAM "TTR1B"

```
1 PRINT "PRIOR TO RUNNING THIS SEQUENCE ENSURE FOLLOWING:"
2 PRINT "ENSURE THAT TTR1 AND TTR1B HAVE THE PROPER FILE NAME IN LINE 441"
3 PRINT "THAT TTR2 LINE 590 HAS PROPER FACTOR IN IT;"
4 PRINT "                    1.01 FOR UNHOODED"
5 PRINT "                     1.02 FOR HOODED                      "
6 PRINT "IF IT IS DESIRED TO RUN A SINGLE POINT, WITHOUT SMOOTHING,TO CHECK"
7 PRINT "DATA,INSERT TTR2-1127 'GO TO 1200'. OTHERWISE,REMOVE THIS LINE."
8 PRINT "IF IT IS DESIRED TO STORE REDUCED DATA,SET TTR6-580 TO".
9 PRINT "'G1=1',OTHERWISE SET G1=0."
10 PRINT "ENSURE THAT TTR6-610,630 HAVE THE PROPER FILE NAME FOR REDUCED DATA"
11 PRINT "ENSURE TTR7-220 HAS THE PROPER FILE NAME FOR RAW DATA"
12 PRINT "ENSURE TTR8-220 HAS THE PROPER FILENAME FOR REDUCED DATA."
17 PRINT "TEAR  THIS OFF AND CONTINUE 20"
18 STOP
19 REM----------*****TTR1B*****-------------------------------------------
20 REM----------DATA REDUCTION FOR TURBINE C/MASS MEMORY-----------------------
21 DISP "LOWEST/HIGHEST RECORD # THIS RUN";
22 INPUT A7,A2
24 A7=A7-1
25 A5=A7
26 F8=A7
27 A6=0
30 DIM C[66],AS[48],QS[20],DS[75],B[10],SS[50],ZS[75],NS[20]
31 DISP "PRINT-OUT RESULTS YES=1,NO=0";
32 INPUT Q5
40 DISP "INPUT NEXT RECORD # FOR DATA2, UNCERT STORAGE FILE";
50 INPUT D
70 MAT A=ZER
80 MAT C=ZER
437 A7=A7+1
438 IF (A7=A2+1) THEN 1401
441 FILES RAWDAT
442 MAT READ # 1,A7;Z
443 FOR I=1 TO 27
```

TABLE A-III (Cont'd)

```
444 C[I]=Z[I]
445 NEXT I
446 FOR I=28 TO 75
447 J=I-27
448 A[J]=Z[I]
449 NEXT I
451 N=C[16]
610 P0=29.92
620 T0=518.7
630 REM----------TEMPERATURES-------------------------------------------------
632 S=1E+03*C[6]
634 T1=FNT(S)+460
640 S=1E+03*C[5]
650 T2=FNT(S)+460
670 S=1E+03*C[2]
680 T5=FNT(S)+460
700 S=1E+03*C[7]
710 T6=FNT(S)+460
750 REM----------PRESSURES ASSIGNMENT-----------------------------------------
752 FOR I=3 TO 48
754 A[I]=(A[I]-A[1])*100/13.596+C[25]*10
756 NEXT I
758 C[17]=(C[17]-A[1])*100/13.596+C[25]*10
760 R9=14.696/P0
770 N8=A[29]*1000
780 N9=A[30]*1000
790 O1=A[31]*1000
800 S3=A[32]*1000
810 S4=A[33]*1000
820 S5=A[34]*1000
830 S6=A[35]*1000
840 S7=A[36]*1000
[illegible]=A[[illegible]]*1000
```

TABLE A-III (Cont'd)

```
860  S9=A[38]*1000
870  N0=A[39]*1000
880  N1=A[40]*1000
890  N2=A[41]*1000
900  N3=A[42]*1000
910  N4=A[43]*1000
920  N5=A[44]*1000
930  N6=A[45]*1000
940  N7=A[46]*1000
950  D0=A[17]*1000
960  D1=A[12]*1000
970  D2=A[18]*1000
980  D3=A[13]*1000
990  D4=A[19]*1000
1000  D5=A[22]*1000
1010  D6=A[14]*1000
1020  D7=A[15]*1000
1030  D8=A[20]*1000
1040  D9=A[23]*1000
1050  E3=A[16]*1000
1060  Q0=A[27]*1000
1070  Q3=A[11]*1000
1080  Q1=1000*((A[6]+A[7]+A[8]+A[9]+A[10])/5)
1090  H0=C[27]*1E+04
1100  P7=A[3]*1000
1110  Q4=C[17]*1000
1120  R8=A[21]*1000
1130  J2=C[25]*10000
1140  REM----------FORCE ASSIGNMENT-----------------------------------------
1150  F4=C[20]*1E+05
1160  F5=C[21]*1E+04
1170  REM----------MOMENT ASSIGNMENT----------------------------------------
1180  M5=C[23]*1E+05
1190  M6=C[24]*1E+05
1200  REM----------STORE RAW DATA IN FILES RAWDAT--------------------------
```

TABLE A-III (Cont'd)

```
1320 CHAIN "TTR2"
1330 END
1340 REM-----------TEMPERATURE SUBROUTINE----------------------------------------
1350 DEF FNT(S)
1360 S1=32.144+35.77*S-0.4518*S↑2
1370 S2=33.252+34.86*S-0.1855*S↑2
1380 IF S1<100 THEN 1400
1390 S1=S2
1400 RETURN S1
1401 STOP
```

TABLE A-IV

PROGRAM "TTR2"

```
10 REM-----*****TTR 2*****---------------------------------------------
20 REM----------PROGRAM TO CALCULATE MASS FLOW RATE-----------------------
30 C1=0.2402
40 J0=778.12
50 C0=53.35
60 C3=32.174
70 G0=0.2867332382
80 C2=3.25
90 C4=7.975
100 C6=0.1148235718
110 C5=C2/C4
120 C7=1
130 C8=1+0.00193*(T5-528)/100
140 C9=1-0.05246*((0.41+0.35*C5↑4)*(H0/P7))
150 K0=(1.153E-05*0.06333*T5↑0.5)/((198.72/T5)+1)
160 P1=Q3/Q0
170 K1=0.8
180 K2=SQR((1-P1↑2)/(10-LOG(P1)))
190 K3=K1*K2*2*PI*6.4*0.0075*Q0
200 W1=K3/(2.036*SQR(53.34*T6/32.174))
210 R1=(6*W1)/(PI*6.4*K0)
220 K=0.601373889233+0.000436695141492*R1
230 K=K-0.000000245308607545*R1↑2
240 K=K+(6.56722336557E-11)*R1↑3
250 K=K-(6.08657310341E-15)*R1↑4
260 IF ABS(K-K1)<0.0001 THEN 361
270 K5=4.36695141492E-04-2*R1*2.45308607545E-07
280 K5=K5+3*R1↑2*6.56722336557E-11
290 K5=K5-4*R1↑3*6.08657310341E-15
300 W2=W1*(1+(K-K1)/(K1-K5*R1))
310 K6=2*PI*6.4*0.0075
320 K7=1/K2
330 K7=(K7*2.036*W2*SQR(53.34*T6/32.174))/(K6*Q0)
340 K1=K7
350 W1=W2
```

TABLE A-IV (Cont'd)

```
360 GOTO 210
361 IF (F8 <= A2) THEN 410
362 IF (Q5=0) THEN 410
370 PRINT
380 PRINT "W-DOT LAB  =";W1
390 PRINT "RE*E-03 LAB=";R1
400 PRINT "K.E. FACTOR=";K
410 W3=C6*C2↑2*C7*C8*C9*(P7*H0/T5)↑0.5
420 R=(C5*48*W3)/(PI*C4*K0*1E+06)
430 K8=1.0272-0.1598*R+0.3805*R↑2
440 W=C6*C2↑2*K8*C8*C9*(P7*H0/T5)↑0.5
450 IF ABS(W-W3)<0.00001 THEN 471
460 W3=W-0.8*(W-W3)
470 GOTO 420
471 W0=W-W1
473 Z9=W0
480 IF (F8 <= A2) THEN 551
481 IF (Q5=0) THEN 540
490 PRINT "KN          =";K8
500 PRINT "W-DOT NOZ  =";W
510 PRINT "RE*E-06 NOZ=";R
520 PRINT "W-DOT      =";W0
530 PRINT
540 REM----------THE NEXT TEN STEPS CALCULATE NEW FLOW RATE BASED ON A GIVEN----
550 REM----------BLOCKAGE FACTOR-----------------------------------------
551 Q2=Q1/P0
552 T3=(T2/T0)↑0.5
560 V9=Z9*T3/Q2
591 IF (F8 <= A2) THEN 610
592 IF (Q5=0) THEN 610
600 PRINT "NEW FLOW RATE=";W0
610 U9=W0*2.036*SQR(C0/C3*T2)/(2.968*Q1)
620 V8=U9/0.68473
621 IF (F8 <= A2) THEN 670
622 IF (Q5=0) THEN 660
```

```
630 PRINT "STATOR FLOW FUNCTION =";U9
640 PRINT "STATOR BLOCKAGE FACTOR=";V8
650 PRINT "   "
660 REM----------THIS PART OF THE PROGRAM EVALUATES CONTROL VOLUME A--------
670 W4=W0/C3
680 P9=(S9+Q3)/2
710 R0=N/T3
720 M0=M5/Q2
730 W5=W0*T3/Q2
740 A1=47.66118069
750 A0=82.51589456
760 REM----------THE NEXT STEPS INTEGRATE EXIT SURFACE PRESSURES OVER THE AREA--
770 F0=N8*0.250005899+N9*0.501457199+O1*0.503384401
780 F1=S3*0.5053116039+S4*0.507238805+S5*0.509166007
790 A8=S6*0.511093209+S7*0.513020411+S8*0.514947613
800 A9=S9*0.516874815+N0*0.518802017+N1*0.520729219
810 B5=N2*0.522656421+N3*0.524583623+N4*0.526510825
820 B6=N5*0.711139415+((N6+N7)/2)*9.619983952
830 B7=1.896906211*Q4
840 F0=F0+F1+A8+A9+B5+B6+B7
850 F2=R8*A1
860 F3=A0*Q3
870 R2=F4+F5+0.491159*(F3-F2-F0)
880 V0=M6/(W4*4.18375)
881 IF (F8 <= A2) THEN 900
882 IF (Q5=0) THEN 900
890 PRINT "V0=";V0
900 V1=109.62*SQR(T2)
901 IF (F8 <= A2) THEN 920
902 IF (Q5=0) THEN 920
910 PRINT "V1=";V1
920 X0=V0/V1
921 IF (F8 <= A2) THEN 931
922 IF (Q5=0) THEN 931
930 PRINT "X0=";X0
```

TABLE A-IV (Cont'd)

```
931 U1=((8.945+7.79)/48)*N*PI/30
932 U2=((9.348+7.6525)/48)*N*PI/30
933 U3=U1/V1
934 U4=U2/V1
935 P4=P9/Q1
936 K4=(1-P4↑G0)/U4↑2
940 DEG
1060 X7=1
1061 V7=W4*V1*2.036/(Q1*15.1809022)
1070 X8=1.402*(2*X7-1)+1
1080 B0=+((R2*2.036)/(Q1*15.1809022))*(1.402*(X7-1)+1)/X8
1090 Z0=0.402*((X7↑2)*V7↑2*(1-X0↑2)-((R2*2.036)/(Q1*15.1809022))↑2)/X8
1100 F8=F8+1
1105 A6=A6+1
1110 IF (F8 <= A2) THEN 1125
1115 P2=((Q4-R8)*(B[1]+B[2]*K4)+R8)/Q1
1116 REM P2=B[1]+B[2]*K4+B[3]*K4↑2+B[4]*K4↑3
1120 GOTO 1200
1125 P2=B0+SQR(B0↑2-Z0)
1126 S0=P2*Q1
1127 GOTO 1200
1130 Q[A6]=K4
1135 D[A6]=(S0-R8)/(Q4-R8)
1136 REM D[A6]=P2
1140 IF (F8<A2) THEN 1165
1145 FILES POLYGA,POLYGD
1150 MAT PRINT # 1;Q
1155 MAT PRINT # 2;D
1160 CHAIN "TTR9"
1165 CHAIN "TTR1B",1,70
1200 X1=P2*(1.402/0.402)/V7
1210 X1=-X1+SQR(X1↑2+1-X0↑2)
1220 X2=SQR(X0↑2+X1↑2)
1230 Z1=1-X2↑2/(1-P2↑G0)
1231 IF (Q5=0) THEN 1260
1240 PRINT "K=";X7
1250 PRINT "    "
1260 CHAIN "TTR3"
```

TABLE A-V

PROGRAM "TTR3"

```
10 REM-----THE NEXT STEPS EVALUATE CONTROL VOLUME B------------------------------
20 REM-----******TTR3*****---------------------------------------------------------
30 REM--------------------------------------------------------------------------------
40 V2=0.98438*V0-(M5/4.25013)/W4
50 G2=3.487562189
60 B1=G2*P9*R9*22.63858979/(W4*V1)
110 X4=(4.18375/4.250125)*X0-((M5/4.250125)/(W4*V1))
120 Z2=(1-X4↑2)-2*(U3*X0-U4*X4)
130 X5=SQR(B1↑2+Z2)-B1
140 L0=(X5↑2+(X4-U4)↑2)
150 L1=((1-X2↑2)*(1-(P9/(P2*Q1))↑G0)+X2↑2-2*X0*U3+U4↑2)
160 Z3=1-L0/L1
170 E0=(M5*PI*N/360)/(0.5*W4*V1↑2*(1-(P9/Q1)↑G0))
200 R3=(P2↑G0-P4↑G0)/(1-P4↑G0)
210 X6=(X4↑2+X5↑2)↑0.5
220 R4=((X6↑2-2*X4*U4)-(X2↑2-2*X0*U3))/(U4↑2+(X6↑2-2*X4*U4))
230 DEG
240 V3=X1*V1
260 A3=ATN(V0/V3)
270 B2=ATN((V0-U1)/V3)
280 V4=X5*V1
290 V5=(V2↑2+V4↑2)↑0.5
300 V6=SQR(V0↑2+V3↑2)
310 DEG
320 A4=ATN(V2/V4)
330 B3=ATN((V2-U2)/V4)
340 M1=(X2/(1-X2↑2)↑0.5)*SQR(5)
350 M2=M1*COS(A3)
360 M3=(X6/(1-X6↑2)↑0.5)*SQR(5)
370 M4=M3*COS(A4)
380 W6=SQR(X1↑2+(X0-U3)↑2)
390 W7=SQR(X5↑2+(U4-X4)↑2)
400 P5=(1-X2↑2)↑(1/G0)
410 P6=Q1/Q3
420 H1=M5*N*PI/(360*550)
```

TABLE A-V (Cont'd)

```
430 H2=H1/(T3*Q2)
440 S0=P2*Q1
450 M7=M6/Q2
460 B4=2*C1*C3*J0
470 T7=T2*(W6↑2-U4↑2-U3↑2+1-X2↑2)
480 DEG
490 W8=W6*(COS(B2-62))
500 T8=T7-T2*W8↑2-T2*(U4↑2-U3↑2)
510 T9=T8*(P4/P2)↑G0
520 W9=SQR(ABS((T7-T9)/T2))
530 Z8=1-W7↑2/W9↑2
540 O0=1-W8↑2/W6↑2
550 U8=1/P2
580 CHAIN "UNCERT"
590 END
```

TABLE A-VI

PROGRAM "UNCERT"

```
10 REM      SUBPROGRAM NAME: UNCERT
20 REM      PROGRAM DISC: TTR
30 REM
40 REM      THIS SUBROUTINE IS DESIGNED TO CALCULATE THE UNCERTAINTY IN RESULTANT
50 REM      AXIAL FORCE, P1/PTO PRESSURE RATIO, AND STATOR LOSS COEFFICIENT.
60 REM
70 REM      VARIABLES ARE AS FOLLOWS:
80 REM
90 REM       N(1)= % UNCERTAINTY IN RESULTANT AXIAL FORCE
100 REM      N(2)= % UNCERTAINTY IN Z0
110 REM      N(3)= INTERMEDIATE CALCULATION= B0↑2-Z0
120 REM      N(4)= % UNCERTAINTY IN U(3)
130 REM      N(5)= % UNCERTAINTY IN PRESSURE RATIO (P1/PTO)
140 REM      N(6)= INTERMEDIATE VARIABLE X1' = 3.487562189*P2/V7
150 REM      N(7)= INTERMEDIATE VARIABLE = U(6)↑2-X0↑2+1
160 REM      N(8)= % UNCERTAINTY IN U(7)
170 REM      N(9)= % UNCERTAINTY IN X1
180 REM      N(10)= % UNCERTAINTY IN X2
190 REM      N(11)= % UNCERTAINTY IN U(12)
200 REM      N(12)= INTERMEDIATE VARIABLE = X2↑2/(1-P2↑G0)
210 REM      N(13)= % UNCERTAINTY IN Z1 (STATOR LOSS COEFFICIENT)
220 REM      N(14)=INTERMEDIATE VARIABLE= L0/L1
230 REM      N(15)= % UNCERTAINTY IN L1
240 REM      N(16)= % UNCERTAINTY IN Z3 (ROTOR LOSS COEFFICIENT)
250 REM      N(17)=R2 (RESULTANT AXIAL FORCE)
260 REM      N(18)= P2 (PRESSURE RATIO P1/PT0)
270 REM      N(19)=Z1 (STATOR LOSS COEFFICIENT)
280 REM      N(20)=Z3 (ROTOR LOSS COEFFICIENT)
290 REM
300 N[1]=1.9966/R2
310 N[2]=(0.167*0.018*(R2/Q1)*2/(V7↑2*(1-X0↑2)-0.018*(R2/Q1)))*N[1]
320 N[3]=B0↑2-Z0
330 N[4]=((2*B0↑2)/N[3])*N[1]
340 N[5]=((B0/(B0+SQR(N[3])))*N[1])↑2
350 N[5]=(N[5]+((0.5*N[3]↑0.5)/(B0+SQR(N[3]))*N[4])↑2)↑0.5
```

TABLE A-VI (Cont'd)

```
360 N[6]=3.487562189*P2/V7
370 N[7]=N[6]↑2-X0↑2+1
380 N[8]=((2*N[6]↑2)/N[7])*N[5]
390 N[9]=(((0.5*N[7]↑0.5)/(N[7]↑0.5-N[6]))*N[8])↑2
400 N[9]=(N[9]+((N[6]/(N[7]↑0.5-N[6]))*N[5])↑2)↑0.5
410 N[10]=(X1↑2/(X0↑2+X1↑2))*N[9]
420 N[11]=2*N[10]
430 N[12]=X2↑2/(1-P2↑G0)
440 N[13]=(N[12]/(1-N[12]))*N[11]
450 N[14]=L0/L1
460 N[15]=((2*X2↑2)/L1)*N[10]
470 N[16]=(N[14]/(1-N[14]))*N[15]
480 N[17]=R2
490 N[18]=P2
500 N[19]=Z1
510 N[20]=Z3
520 FILES DATA2
530 MAT PRINT # 1,D;N
540 PRINT "UNCERTAINTY DATA IS STORED IN FILE/DATA2/RECORD"D
542 PRINT
544 PRINT
550 D=D+1
560 CHAIN "TTR4"
570 END
```

TABLE A-VII

PROGRAM "TTR4"

```
10 REM-----------*****TTR4*****------------------------------------------------
20 REM-----THIS PROGRAM ESTIMATES STATOR VELOCITIES AND--------------------------
30 REM----------LIST PRESSURE RATIOS--------------------------------------------
40 I0=D0/Q1
50 I1=D1/Q1
60 I2=D2/Q1
70 I3=D3/Q1
80 I4=D4/Q1
90 I5=D5/Q1
100 I6=D6/Q1
110 I7=D7/Q1
120 I8=D8/Q1
130 I9=D9/Q1
140 J7=E3/Q1
150 Y0=SQR(1-I0↑0.2857142857)
160 Y1=SQR(1-I1↑0.2857142857)
170 Y2=SQR(1-I2↑0.2857142857)
180 Y3=SQR(1-I3↑0.2857142857)
190 Y4=SQR(1-I4↑0.2857142857)
200 Y5=SQR(1-I5↑0.2857142857)
210 Y6=SQR(1-I6↑0.2857142857)
220 Y7=SQR(1-I7↑0.2857142857)
230 Y8=SQR(1-I8↑0.2857142857)
240 Y9=SQR(1-I9↑0.2857142857)
250 Z6=SQR(1-J7↑0.2857142857)
260 L2=(Y0/(1-Y0↑2)↑0.5)*SQR(5)
270 L3=(Y1/(1-Y1↑2)↑0.5)*SQR(5)
280 L4=(Y2/(1-Y2↑2)↑0.5)*SQR(5)
290 L5=(Y3/(1-Y3↑2)↑0.5)*SQR(5)
300 L6=(Y4/(1-Y4↑2)↑0.5)*SQR(5)
310 L7=(Y5/(1-Y5↑2)↑0.5)*SQR(5)
320 L8=(Y6/(1-Y6↑2)↑0.5)*SQR(5)
330 L9=(Y7/(1-Y7↑2)↑0.5)*SQR(5)
340 O2=Y0*V1
350 O3=Y1*V1
```

TABLE A-VII (Cont'd)

```
360 O4=Y2*V1
370 O5=Y3*V1
380 O6=Y4*V1
390 O7=Y5*V1
400 O8=Y6*V1
410 O9=Y7*V1
420 J=(Y8/(1-Y8↑2)↑0.5)*SQR(5)
430 M8=(Y9/(1-Y9↑2)↑0.5)*SQR(5)
440 M9=(Z6/(1-Z6↑2)↑0.5)*SQR(5)
450 J6=Y8*V1
460 J8=Y9*V1
470 J9=Z6*V1
480 REM-----THIS SECTION CALCULATES THEOR. LOSS COEFFICIENT;SETS THEM EQUAL TO--
490 REM------ZERO FIRST SO THAT THEY ARE DEFINED------------------------------
500 E8=0
510 E9=0
550 E4=0.045
555 Q6=((1-X2↑2)↑2.48756)*X1
560 Q7=1.153E-05*(0.06333*SQR(T2)/((198.72/T2)+1))
561 Q8=(Q6*0.0807223*Q1*492*V1*1.6621)/(Q7*29.92*T2)
562 H5=12*(1/Q8↑0.2)
565 J4=2.441811-4.40721*L9+4.047785*L9↑2-1.003885*L9↑3
570 H6=1+2*(0.3051-0.2)
580 E5=E4*H6*H5*J4
590 E6=((0.0323*75*0.3554)*(1+0.962*E5))/(1-0.03*75*0.3554*E5)*E5
600 F6=(0.055/0.848+0.962*E5)/(1+0.962*E5)
610 F7=(COS(75))↑2*(F6/(1-F6))↑2
620 E7=F7/(1+F7)
630 E8=E5+E6+E7
640 B8=B2-B3
650 B2=-B2
700 J3=0.0256429-0.0005119*B2+0.0000119*B2↑2
```

```
701 B2=-B2
710 H8=1.42835E-04*(0.06333*SQR(T8)/((198.72/T8)+1))*(29.92/S0)*(T8/492)
720 H9=W6*V1*1.0775/(H8*12)
760 T4=12*(1/H9↑0.2)
770 F9=1+2*(0.4367-0.2)
810 J4=1
820 J5=J3*T4*F9*J4
830 G8=(0.0323*B8*0.5291*COS(B3)*(1+0.962*J5))
840 X9=1-(0.03*B8*0.5291*COS(B3)*J5)
850 G8=G8/X9*J5
860 G9=(0.026/0.444+0.962*J5)/(1+0.962*J5)
870 B9=(COS(B3))↑2*(G9/(1-G9))↑2
880 U0=B9/(1+B9)
890 U5=1.13
900 U6=U5*(0.012/0.78975)/SQR(0.656/0.444)*(TAN(B2)-TAN(B3))↑1.5
910 Z7=((COS(B3))↑2/(COS(ATN((TAN(B2)+TAN(B3))/2))))
920 U6=U6*Z7
930 U7=U6/(1+U6)
940 E9=J5+G8+U0+U7
941 Z4=S0/((D7+D8)/2)
942 R6=((1+0.201*(L9↑2))↑G2)-Z4*((1+0.201*(M1↑2))↑G2)
943 R6=R6/(((1+0.201*(M1↑2))↑G2)-1)
950 CHAIN "TTR5"
960 END
```

TABLE A-VIII

PROGRAM "TTR5"

```
10 REM-----*****TTR5*****------------------------------------------------------------
20 REM-----PRINT REDUCED DATA-------------------------------------------------------
21 IF (Q5=0) THEN 770
60 WRITE (15,70)C[10],C[11]
70 FORMAT "RUN",F4.0,2X,"PT.",F4.0,"      TURBINE CONFIGURATION C"
80 PRINT
85 PRINT "TT0  =";T2
90 PRINT "PRESSURE RATIO      =";P6
92 PRINT "MEAS TURB FLOW RATE=";Z9
96 PRINT "MEAS REF FLOW RATE=";V9
100 PRINT "REF FLOW RATE       =";W5
105 PRINT "TURB NOZ RE NO.     =";Q8
110 PRINT "REF RPM             =";R0
120 PRINT "REF ROTOR MOMENT    =";M0
130 PRINT "REF HP              =";H2
140 PRINT "EFF. T-S            =";E0
150 PRINT
151 PRINT "RATIOS OF PRESSURE AND TEMPERATURES TO REFERENCE"
153 PRINT "DELTA=";Q2
154 PRINT "THETA=";(T3)↑2
156 PRINT " "
157 PRINT "LOSS COEFFICIENTS"
170 PRINT "STATOR LOSS THEOR. =";E8
180 PRINT "STATOR LOSS COEFF. =";Z1
190 PRINT "ROTOR LOSS COEFF.  =";Z3
210 PRINT "ROTOR LOSS THEOR.  =";E9
220 PRINT "-----------------------------------------------------------------------
230 PRINT "ISEN. HEAD COEFF.     =";K4
240 PRINT "TH. DEG. OF REACTION =";R3
250 PRINT "ACT. DEG. OF REACTION=";R4
260 PRINT
270 PRINT "VELOCITY TRIANGLE DATA"
280 PRINT
290 WRITE (15,300)V6,V5
300 FORMAT "V1 =",F11.5,3X,"V2 =",F11.5
310 WRITE (15,320)V3,V4
```

```
320 FORMAT "VA1=",F11.5,3X,"VA2=",F11.5
330 WRITE (15,340)V0,V2
340 FORMAT "VU1=",F11.5,3X,"VU2=",F11.5
350 PRINT " "
360 WRITE (15,370)A3,A4
370 FORMAT "ALPHA 1=",F11.5,3X,"ALPHA 2=",F11.5
380 WRITE (15,390)B2,B3
390 FORMAT "BETA 1 =",F11.5,3X,"BETA 2 =",F11.5
400 PRINT " "
410 PRINT "MACH NO. DATA"
420 PRINT " "
430 PRINT "MACH AT 1       =";M1
440 PRINT "AXIAL MACH AT 1=";M2
450 PRINT "MACH AT 2       =";M3
460 PRINT "AXIAL MACH AT 2="M4
470 PRINT " "
480 PRINT "PRESSURE INFORMATION"
490 PRINT " "
500 PRINT "P1/PT1=";P5
510 PRINT "PT0/P1=";U8
530 PRINT "P1    =";S0
534 WRITE (15,538)Q4/Q1,1/U8,R8/Q1
538 FORMAT /,"PTIP/PTO  =",F10.6,/,"P1/PTO     =",F10.6,/,"PHUB/PTO  =",F10.6
550 PRINT " "
560 PRINT "LOSS COEFF. DUE TO OFF-DESIGN IMPINGEMENT ANGLE=";O0
570 PRINT "ROTOR LOSS COEFF. (OTHER FACTORS)=";Z8
580 PRINT "REF. STATOR MOMENT=";M7
590 PRINT " "
600 PRINT " "
610 PRINT "STATOR VELOCITIES AND MACH #'S FOLLOW (FORE TO AFT):"
620 PRINT " "
630 PRINT "()'S CORR. TO TAP HOLE #'S; SEE DRWG. #1207:"
640 PRINT " "
650 PRINT "V(6)=";O2,TAB18,"M(6)=";L2,TAB35"INLET"
660 PRINT "V(1)=";O3,TAB15,"M(1)=";L3,TAB35"INLET"
```

TABLE A-VIII (Cont'd)

```
670 PRINT "V(7)=";O4,TAB15,"M(7)=";L4,TAB35"INLET"
680 PRINT "V(2)=";O5,TAB15,"M(2)=";L5,TAB35"THROAT-M.L."
690 PRINT "V(8)=";O6,TAB15,"M(8)=";L6,TAB35"THROAT-HUB"
700 PRINT "V TH-TIP=";O7,TAB15"M TH-TIP=";L7,TAB35"THROAT-TIP"
710 PRINT "V(3)=";O8,TAB15,"M(3)=";L8,TAB35"SS-AFT"
720 PRINT "V(4)=";O9,TAB15,"M(4)=";L9,TAB35"EXIT-M.L."
730 PRINT "V(9)=";J6,TAB15,"M(9)=";J,TAB35"EXIT-HUB"
740 PRINT "V EX-TIP=";J8,TAB15,"M EX-TIP=";M8,TAB35"EXIT-TIP"
750 PRINT "V(5)=";J9,TAB15,"M(5)=";M9,TAB35"SS-AFT"
751 PRINT " "
752 PRINT " "
753 PRINT "AFTER EXPANSION LOSS DATA"
756 PRINT "AFTER EXPANSION LOSS COEF.=";R6
770 CHAIN "TTR6"
780 END
```

TABLE A-IX

PROGRAM "TTR6"

```
10 REM-----*****TTR6*****----------------------------------------------------------------
20 REM-----STORE REDUCED DATA IN REDDAT---------------------------------------------------
30 D[1]=R0
40 D[2]=W5
50 D[3]=M0
60 D[4]=E0
70 D[5]=V6
80 D[6]=V5
90 D[7]=V3
100 D[8]=V4
110 D[9]=V0
120 D[10]=V2
130 D[11]=Z1
140 D[12]=Z3
150 D[13]=R3
160 D[14]=R4
170 D[15]=K4
180 D[16]=A3
190 D[17]=A4
200 D[18]=B2
210 D[19]=B3
220 D[20]=P6
230 D[21]=M1
240 D[22]=M2
250 D[23]=M3
260 D[24]=M4
270 D[25]=H2
280 D[26]=M7
290 D[27]=O0
300 D[28]=Z8
310 D[29]=I0
320 D[30]=I1
330 D[31]=I2
340 D[32]=I3
350 D[33]=I4
```

TABLE A-IX (Cont'd)

```
360  D[ 34 ]=I5
370  D[ 35 ]=I6
380  D[ 36 ]=I7
390  D[ 37 ]=I8
400  D[ 38 ]=I9
410  D[ 39 ]=J7
420  D[ 40 ]=U8
430  D[ 41 ]=N
440  D[ 42 ]=V8
450  D[ 43 ]=E8
460  D[ 44 ]=E9
470  D[ 45 ]=C[ 10 ]
480  D[ 46 ]=C[ 11 ]
490  D[ 47 ]=C[ 12 ]
500  D[ 48 ]=C[ 13 ]
510  D[ 49 ]=C[ 14 ]
515  D[ 50 ]=R6
516  D[ 51 ]=Q2
517  D[ 52 ]=(T3)↑2
520  D[ 53 ]=Z9
525  D[ 54 ]=V9
530  D[ 55 ]=O8
532  D[ 56 ]=H1
534  D[ 57 ]=M5
536  D[ 58 ]=M6
538  D[ 59 ]=F4
540  D[ 60 ]=F5
542  D[ 61 ]=R2
544  D[ 62 ]=Q1
546  D[ 63 ]=T2
548  D[ 64 ]=Q3
550  D[ 65 ]=Q4
552  D[ 66 ]=S0
554  D[ 67 ]=R8
556  D[ 68 ]=Q4/Q1
```

TABLE A-IX (Cont'd)

```
558 D[69]=P2
560 D[70]=R8/Q1
562 D[71]=T2-T1
580 G1=1
590 IF G1=0 THEN 660
610 FILES REDDAT
620 MAT PRINT # 1,A7;D
630 PRINT "REDUCED DATA IS STORED IN FILE/REDDAT/RECORD"A7
640 PRINT
650 GOTO 670
660 PRINT "THIS DATA WAS NOT STORED"
670 PRINT
680 PRINT
690 CHAIN "TTR1B",1,70
692 STOP
710 REM------CHAIN OPTIONS WITH TABULATION PROGRAMS------------------------------
740 IF (A7<A2) THEN 820
741 IF (Q5=0) THEN 830
750 GET "TTR7",850,850
820 CHAIN "TTR1",1,70
830 STOP
840 END
```

TABLE A-X

PROGRAM "TTR7"

```
10 DIM C$[27],A$[48],P$[15,48],R$[15,27],U$[15],V$[15],W$[15],X$[15],Y$[15]
20 DIM Z$[15]
30 REM---------*****TTR7*****---------------------------------------------------
40 REM-------PROGRAM TO TABULATE RAW DATA FROM TTR------------------------------
50 REM-------USING MASS MEMORY FILES--------------------------------------------
60 MAT R=ZER
70 MAT P=ZER
80 MAT U=ZER
90 MAT V=ZER
100 MAT W=ZER
110 MAT X=ZER
120 MAT Y=ZER
130 MAT Z=ZER
140 DISP "ENTER RECORD #'S:LOWEST,HIGHEST";
150 INPUT A7,A2
180 L=1
190 FOR K=A7 TO A2
220 FILES RAWDAT
230 MAT READ # 1,K;C,A
240 FOR J=1 TO 48
250 P[L,J]=A[J]
260 NEXT J
270 U[L]=C[10]
280 V[L]=C[11]
290 W[L]=C[12]
300 X[L]=C[13]
310 Y[L]=C[14]
320 Z[L]=C[16]
330 FOR I=1 TO 27
332 IF I=8 THEN 348
334 IF I=22 THEN 350
340 R[L,I]=C[I]
346 GOTO 350
348 I=I+11
350 NEXT I
360 L=L+1
370 NEXT K
```

TABLE A-X (Cont'd)

```
410 PRINT TAB40"TABLE XXII"
420 PRINT
430 PRINT TAB38"TTR INPUT DATA"
440 PRINT TAB38"--------------"
480 FOR J=1 TO 48 STEP 6
490 WRITE (15,500)J,J+1,J+2,J+3,J+4,J+5
500 FORMAT /,9X,"PORT NO.",3X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0
510 PRINT "          RUN PT."
520 FOR K=1 TO L-1
530 WRITE (15,540)U[K],V[K],P[K,J],P[K,J+1],P[K,J+2],P[K,J+3],P[K,J+4],P[K,J+5]
540 FORMAT 7X,2F4.0,2X,6F10.6
550 NEXT K
560 NEXT J
580 FOR I=0 TO 27 STEP 5
582 IF I=5 THEN 604
590 WRITE (15,600)I,I+1,I+2,I+3,I+4
600 FORMAT /,9X,"CHANNEL  ",F4.0,6X,F4.0,6X,F4.0,6X,F4.0,6X,F4.0,9X,"RPM"
602 GOTO 610
604 WRITE (15,600)I,I+1,I+15,I+16,I+18
610 PRINT "          RUN PT"
620 FOR K=1 TO L-1
621 IF I=5 THEN 634
622 IF I#0 THEN 630
624 I=1
630 WRITE (15,640)U[K],V[K],R[K,I],R[K,I+1],R[K,I+2],R[K,I+3],R[K,I+4],Z[K]
632 GOTO 650
634 WRITE (15,640)U[K],V[K],R[K,I+1],R[K,I+2],R[K,I+15],R[K,I+16],R[K,I+18],Z[K]
640 FORMAT 7X,2F4.0,5F10.6,F10.0
650 NEXT K
652 IF I#1 THEN 656
654 I=0
656 IF I#5 THEN 660
658 I=I+13
660 NEXT I
680 PRINT
690 PRINT
760 GET "TTR8"
770 STOP
780 END
```

TABLE A-XI

PROGRAM "TTR8"

```
10 DIM DS[71],GS[15,71]
20 REM-----------*****TTR8*****---------------------------------------------------------
30 REM-----------PROGRAM TO TABULATE REDUCED DATA FOR TTR-------------------------------
40 REM-----------USING MASS MEMORY FILES------------------------------------------------
50 PRINT
60 PRINT
70 PRINT
80 PRINT
90 PRINT
100 PRINT
110 R=18
120 S=19
130 T=13
140 U=14
150 DISP "ENTER LOWEST,HIGHEST REC#";
160 INPUT A7,A2
170 I=1
180 FOR K=A7 TO A2
190 FILES REDDAT
200 MAT READ # 1,K;D
210 FOR J=1 TO 71
220 G[I,J]=D[J]
230 NEXT J
240 I=I+1
250 NEXT K
260 M=I-1
270 DISP "ENTER RUN #";
280 INPUT Y
290 PRINT TAB36"TABLE IV"
300 WRITE (15,310)Y
310 FORMAT 30X,"RUN",F3.0,2X,"REDUCED DATA"
320 PRINT
330 PRINT TAB32"VELOCITY TRIANGLE"
340 FORMAT 7X,"PT.",6X,"V1",8X,"V2",8X,"VA1",7X,"VA2",7X,F10.6
350 WRITE (15,340)"VU1","        VU2"
```

TABLE A-XI (Cont'd)

```
360 FOR I=1 TO M
370 WRITE (15,380)I,G[I,5],G[I,6],G[I,7],G[I,8],G[I,9],G[I,10]
380 FORMAT 7X,F3.0,6F10.1
390 NEXT I
400 PRINT "          ----------------------------------------------------------------"
410 PRINT TAB25"MACH NUMBERS";TAB56"ANGLES"
420 FORMAT 7X,"PT.",5X,"M1",5X,"MA1",6X,"M2",5X,"MA2",5X,"A1",6X,"A2",2X,F6.2
430 WRITE (15,420)"  B1","      B2"
440 FOR I=1 TO M
450 WRITE (15,460)I,G[I,21],G[I,22],G[I,23],G[I,24],G[I,16],G[I,17],G[I,R],G[I,S
460 FORMAT 7X,F3.0,4F8.3,4F7.1
470 NEXT I
480 PRINT "          ----------------------------------------------------------------"
490 PRINT TAB37"LOSSES"
500 FORMAT 7X,"PT.",5X,"ZS",6X,"ZSTH",6X,"ZR",6X,"ZRTH",6X,"ZR*",5X,"ZI",7X,"Y"
510 WRITE (15,500)
520 FOR I=1 TO M
530 WRITE (15,540)I,G[I,11],G[I,43],G[I,12],G[I,44],G[I,28],G[I,27],G[I,50]
540 FORMAT 7X,F3.0,5F9.4,E10.1,F7.3
550 NEXT I
560 PRINT "          ----------------------------------------------------------------"
570 PRINT " "
580 PRINT " "
590 PRINT " "
600 PRINT " "
610 PRINT " "
620 PRINT " "
630 PRINT " "
640 PRINT " "
650 PRINT " "
660 WRITE (15,310)Y
670 PRINT " "
680 FORMAT 7X,"PT.",3X,"P.R.",3X,"STPR",6X,"H.P.",7X,"RTM",7X,"STM",F5.1
690 WRITE (15,680)"        AXF","           CLF"
700 FOR I=1 TO M
```

TABLE A-XI (Cont'd)

```
710 WRITE (15,720)I,G[I,20],G[I,40],G[I,56],G[I,57],G[I,58],G[I,59],G[I,60]
720 FORMAT 7X,F3.0,2F7.2,1X,F9.2,4F11.2
730 NEXT I
740 PRINT "         ----------------------------------------------------------------"
750 FORMAT 7X,"PT.",3X,"MW-DOT",7X,"PTO",5X,"TTO",7X,"PHD",6X,"P-TIP",F7.1
760 WRITE (15,750)"      P1","       P-HUB"
770 FOR I=1 TO M
780 WRITE (15,790)I,G[I,53],G[I,62],G[I,63],G[I,64],G[I,65],G[I,66],G[I,67]
790 FORMAT 7X,F3.0,F11.5,F9.3,F8.1,4F10.3
800 NEXT I
810 PRINT "         ----------------------------------------------------------------"
820 FORMAT 7X,"PT.",3X,"PTIP/PTO",3X,"P1/PTO",3X,"PHUB/PTO",4X,"KIS",F3.1
830 WRITE (15,820)"     TURB RE","    DEL T","      ETA"
840 FOR I=1 TO M
850 WRITE (15,860)I,G[I,68],G[I,69],G[I,70],G[I,15],G[I,55],G[I,71],G[I,4]
860 FORMAT 7X,F3.0,4F10.3,F10.0,F10.2,F8.3
870 NEXT I
880 PRINT "         ----------------------------------------------------------------"
890 FORMAT 7X,"PT.",3X,"DELTA",3X,"THETA",4X,"RHP",6X,"RMW-DOT",5X,"RRTM",F8.2
900 WRITE (15,890)"       RSTM","           RN"
910 FOR I=1 TO M
920 WRITE (15,930)I,G[I,51],G[I,52],G[I,25],G[I,54],G[I,3],G[I,26],G[I,1]
930 FORMAT 7X,F3.0,2F8.3,F9.3,F11.5,2F11.3,F10.0
940 NEXT I
950 PRINT "         ----------------------------------------------------------------"
960 FORMAT 7X,"PT.",3X,"RTH",4X,"REFF",6X,"RAF",7X,"RPM"
970 WRITE (15,960)
980 FOR I=1 TO M
990 WRITE (15,1000)I,G[I,T],G[I,U],G[I,61],G[I,41]
1000 FORMAT 7X,F3.0,2F7.2,F10.2,F10.0
1010 NEXT I
1015 PRINT "      ------------------------------------------------------------------"
1017 PRINT
1020 PRINT TAB30"NOZZLE PRESSURE RATIOS"
1030 FORMAT 7X,"PT.",5X,"P1",6X,"P2",6X,"P3",6X,"P4",6X,"P5",6X,"P6",6X,F9.2
```

TABLE A-XI (Cont'd)

```
1040 WRITE (15,1030)"P7"
1050 FOR I=1 TO M
1060 WRITE (15,1070)I,G[I,30],G[I,32],G[I,35],G[I,36],G[I,39],G[I,29],G[I,31]
1070 FORMAT 7X,F3.0,7F8.3
1080 NEXT I
1090 PRINT "          ------------------------------------------------------------------------
1100 FORMAT 7X,"PT.",5X,"P8",6X,"P9"
1110 WRITE (15,1100)
1120 FOR I=1 TO M
1130 WRITE (15,1140)I,G[I,33],G[I,37]
1140 FORMAT 7X,F3.0,2F8.3
1150 NEXT I
1160 STOP
1170 PRINT "          -------------------DATA TABULATION COMPLETE------------------
1180 DISP "CHAIN WITH TTR1";
1190 WAIT 3000
1200 GET "TTR1"
1210 STOP
1220 END
```

TABLE A-XII

PROGRAM "TTR11"

```
10 DIM NS[20],GS[15,28]
20 REM      PROGRAM NAME: TTR11
30 REM      PROGRAM DISC: TTR
40 REM
50 REM      PROGRAM DISCRIPTION: THIS PROGRAM IS DESIGNED TO BATCH PROCESS
60 REM      THE UNCERTAINTY DATA FROM RIG RUNS.
70 REM
80 DISP "ENTER LOWEST/HIGHEST RECORD #";
90 INPUT A7,A2
100 I=1
110 FOR K=A7 TO A2
120 FILES DATA2
130 MAT READ # 1,K;N
140 FOR J=1 TO 20
150 G[I,J]=N[J]
160 NEXT J
170 G[I,21]=N[1]*N[17]
180 G[I,22]=N[1]*100
190 G[I,23]=N[18]*N[15]
200 G[I,24]=N[5]*100
210 G[I,25]=N[13]*N[19]
220 G[I,26]=N[13]*100
230 G[I,27]=N[20]*N[16]
240 G[I,28]=N[16]*100
250 I=I+1
260 NEXT K
270 M=I-1
280 DISP "ENTER RUN #";
290 INPUT Y
300 PRINT
310 PRINT
320 PRINT TAB36"TABLE II"
330 WRITE (15,340)Y
340 FORMAT 28X,"RUN",F3.0,2X,"UNCERTAINTY DATA"
357 PRINT
```

```
360 FORMAT 7X,"PT.",5X,"RAF",7X,"+/-",5X,"% ERROR",5X,"P1/PTO",7X,"+/-",6X,F8.0
370 WRITE (15,360)"% ERROR"
380 FOR I=1 TO M
390 WRITE (15,400)I,G[I,17],G[I,21],G[I,22],G[I,18],G[I,23],G[I,24]
400 FORMAT 6X,F3.0,F10.2,2F10.3,2F12.4,F10.3
410 NEXT I
420 PRINT
430 PRINT
440 FORMAT 7X,"PT.",6X,"Z1",6X,"+/-",6X,"% ERROR",8X,"Z3",8X,"+/-",6X,"% ERROR"
450 WRITE (15,440)
460 FOR I=1 TO M
470 WRITE (15,480)I,G[I,19],G[I,25],G[I,26],G[I,20],G[I,27],G[I,28]
480 FORMAT 6X,F3.0,2F10.4,F10.2,2F12.4,F10.2
490 NEXT I
500 PRINT
510 PRINT
520 PRINT
530 STOP
540 END
```

TABLE A-XIII

VARIABLES ADDED/MODIFIED TO THE REDUCTION PROGRAMS

T1	Expression for turbine outlet temperature
Z9	Expression for computed flow rate
V9	Expression for computed referred flow rate
WØ	Modified in meaning - was equal to $\dot{W}$ based on a constant 1.02 lbm/sec flow rate in previous programs (see Ref. 1). Now is equivalent to Z9, computed $\dot{W}$.

TABLE A-XIV

PLOT ROUTINES

PROGRAM	
KPLOT	ζ_S/ζ_R vs. K_{is}
KPLOT1	Referred rotor torque vs. referred RPM
KPLOT2	η_{TS} vs. referred RPM
KPLOT3	η_{TS} vs. axial spacing (in)
KPLOT4	η_{TS} vs. K_{is}
KPLOT5	Referred HP vs. referred RPM
KPLOT6	ζ_R vs. axial spacing (in)
KPLOT7	After expansion (Y) vs. pressure ratio (stator)
KPLOT8	Loss coefficient (Y) vs. K_{is}
KPLOT9	Y vs. P_1/P_{exit}
PLOTØ	Stator pressure ratio (P_{t_o}/P_1) vs. K_{is}
BPLOT	Actual/theoretical degree of reaction vs. K_{is}
BPLOT1	$\dot{W}_{ref}$ vs. K_{is}
BPLOT2	Incident loss coefficient vs. K_{is}
BPLOT5	Max efficiency/Max. global efficiency vs. Axial spacing/rotor blade height

BPLOT6	ζ_S vs. stator pressure ratio
TPLOT3	Rotor shroud pressure ratio vs. shroud tap points
TPLOT4	Stator suction side pressure ratio vs. stator nozzle tap
TPLOT5	Pressure ratio (P_1/P_{t_o}) vs. K_{is}
TPLOT6	Resultant axial force vs. K_{is}
TPLOT7	Referred stator torque vs. K_{is}

TABLE A-XV

PROGRAM "RPMSUR"

```
10 REM      PROGRAM NAME: RPMSUR
20 REM
30 REM*****PROGRAM TO EXAMINE TURBINE RPM VARIATIONS WITH TIME*******************
40 REM
50 REM
60 PRINT
70 PRINT
80 DIM M$[3,120],N$[120],P$[120],Q$[120],C$[3]
90 MAT M=ZER
100 MAT N=ZER
110 MAT P=ZER
120 MAT Q=ZER
130 MAT C=ZER
140 PRINT "CHECK LINES 290,310-400 FOR PROPER SCALING FACTORS"
150 PRINT
160 PRINT
170 DISP "READY PLOTTER WITH PAPER";
180 STOP
190 DISP "ENTER NEXT RECORD #,DATE (MO,DA,YR)";
200 INPUT E1,C[1],C[2],C[3]
210 GOSUB 290
220 DISP "PRESS CONT WHEN READY TO RECORD RPM PTS";
230 STOP
240 GOSUB 680
250 GOSUB 900
260 GOSUB 1000
270 STOP
280 END
290 SCALE -30,390,17500,20500
300 LABEL (*,1.2,1.7,0,17/25)
310 X0=20
320 X1=0
330 X2=360
340 X3=20
350 X4=20
```

TABLE A-XV (Cont'd)

```
360 Y0=200
370 Y1=17700
380 Y2=20300
390 Y3=17900
400 Y4=200
410 XAXIS Y1,X0,X1,X2
420 YAXIS X2,Y0,Y1,Y2
430 YAXIS X1,Y0,Y1,Y2
440 XAXIS Y2,X0,X1,X2
450 REM*****LABEL AXES***********************************************************
460 FOR X9=X3 TO X2 STEP X4
470 PLOT X9,Y1
480 CPLOT -2,-1
490 FORMAT F5.0
500 LABEL (*)X9
510 NEXT X9
520 FOR Y9=Y3 TO Y2 STEP Y4
530 PLOT X1,Y9
540 CPLOT -6,-0.3
550 FORMAT F5.1
560 LABEL (*)Y9
570 NEXT Y9
580 REM*****NAME AXES************************************************************
590 PLOT (X1+X2)/2,Y1,1
600 CPLOT -13,-3
610 LABEL (*)"SAMPLES (ABOUT 330 PER MIN)"
620 LABEL (*,1.2,1.7,PI/2,17/25)
630 PLOT X1,(Y1+Y2)/2,1
640 CPLOT -2,5
650 LABEL (*)"RPM"
660 RETURN
670 END
680 REM*****SUBROUTINE TO RECORD RPM*********************************************
690 DIM S$[3]
700 FORMAT 4B
```

TABLE A-XV (Cont'd)

```
710 FORMAT F3.0
720 FORMAT 3B
730 OUTPUT (13,700)256,20,768,512;
740 CMD "?D%","PF4G5S6"
750 CMD "?D!"
760 OUTPUT (13,710)16
770 FOR J=1 TO 3
780 FOR I=1 TO 120
790 CMD "?D%"
800 OUTPUT (13,720)256,8,512;
810 CMD "?E$"
820 ENTER (13,*)Y
830 Y=Y*2
840 M[J,I]=Y
850 NEXT I
860 NEXT J
865 CMD "?D!","C"
870 RETURN
880 END
890 REM     SUBROUTINE TO PLOT RPM POINT
900 L=1
910 FOR J=1 TO 3
920 FOR I=1 TO 120
930 LABEL (*,1,1,0,1)
940 PLOT L,M[J,I]
950 L=L+1
960 NEXT I
970 NEXT J
980 RETURN
990 END
1000 REM*****SUBROUTINE TO STORE RPM DATA****************************************
1010 FILES RPMSTO
1020 FOR I=1 TO 120
1030 N[I]=M[1,I]
1040 P[I]=M[2,I]
1050 Q[I]=M[3,I]
```

TABLE A-XV (Cont'd)

```
1060 NEXT I
1070 MAT PRINT # 1,E1;N
1080 MAT PRINT # 1,E1+1;P
1090 MAT PRINT # 1,E1+2;Q,C
1100 WRITE (15,1110)E1,E1+1,E1+2
1110 FORMAT "THE RAW DATA IS STORED ON RPMSTO RECORD #",F3.0,",",F3.0,"AND",F3.0
1120 E1=E1+3
1130 RETURN
1140 END
```

TABLE A-XVI

PROGRAM "TERRY7"

```
10 REM PROGRAM NAME:   TERRY7
20 REM PROGRAM DISCRIPTION: DESIGNED TO TABULATE, CALCULATE, AND COMPARE ACTUAL
30 REM                DELTA TEMPS ACROSS THE STAGE WITH DELTA TEMPS NECESSARY TO
40 REM                PRODUCE THE CALCULATED HORSEPOWER.  DELTA TEMP OF THE H.P. IS
50 REM                COMPUTED USING REFERRED H.P. AND REFERRED MASS FLOW.
60 REM
70 DIM DS[71],G[15,71],X[15,2]
71 PRINT
72 PRINT
73 PRINT TAB34"TABLE XVI"
74 PRINT
75 PRINT TAB20"TEMPERATURE DROP CALCULATED FROM THE"
76 PRINT TAB21"MEASURED POWER AND MEASURED VALUES"
77 PRINT
80 DISP "ENTER LOWEST, HIGHEST RECORD #";
90 INPUT A7,A2
100 I=1
110 FOR K=A7 TO A2
120 FILES REDDAT
130 MAT READ # 1,K;D
140 FOR J=1 TO 71
150 G[I,J]=D[J]
160 NEXT J
170 X[I,1]=G[I,25]*G[I,52]/((778.16/550)*G[I,54]*0.24)
175 X[I,2]=G[I,71]-X[I,1]
180 I=I+1
190 NEXT K
200 M=I-1
230 PRINT TAB35"RUN "G[M,45]
240 PRINT
250 PRINT
260 FORMAT 7X,"PT.",4X,"H.P.",4X,"R-H.P.",2X,"RMW-DOT",4X,"TTO",F5.2
270 WRITE (15,260)"     DEL T","  C-DEL T","  DIFF"
280 PRINT
290 FOR I=1 TO M
```

TABLE A-XVI (Cont'd)

```
300 WRITE (15,310)I,G[I,56],G[I,25],G[I,54],G[I,63],G[I,71],X[I,1],X[I,2]
310 FORMAT 6X,F3.0,2F9.2,F10.5,3F8.1,F7.1
320 NEXT I
330 PRINT
340 PRINT
350 PRINT
360 PRINT
370 PRINT
380 STOP
390 END
```

TABLE A-XVII

PROGRAMS USED FOR ACQUIRING, MODIFYING, OR REDUCING DATA

PROGRAM	USE
SCAMOD	Acquires raw data for turbine performance tests
TTRIB	Recalls raw data from storage. Assigns scaling factors.
TTR2	Calculates $\dot{W}_{LAB}$, $\dot{W}$, $\dot{W}_{ref}$, and calculates parameters in stator control volume (ζ_S, etc.)
TTR3	Calculates parameters in rotor control volume (ζ_R, etc.)
UNCERT	Calculates uncertainties in RAF, P_1/P_{Z0}, ζ_S, and ζ_R
TTR4	Calculates stator velocities and theoretical loss coefficients
TTR5	Prints out results for each reduced data point
TTR6	Stores reduced data

TTR7	Tabulates raw data
TTR8	Tabulates reduced data
TTR11	Tabulates uncertainty data
RPMSUR	Takes 360 RPM samples at a rate of 330/min and stores them on a set of 3 sequential record numbers
TERRY7	Compares actual and computed temperature differences across the stage based on horsepower calculations

TABLE A-XVIII

WAVEFORM ANALYSIS PROGRAM MODIFICATIONS
TO ACCEPT TIME DOMAIN DATA

Statement #	Statement
2520 (Current Program Statement OK)	OFF ERROR
2521 (Begin Modification)	FOR I = 1 TO 128
2530	READ #1; Real(I)
2531	NEXT I
2532	FOR I = 1 TO 128
2533	READ #1; Imag(I)
2534	NEXT I
2540 (This Program Statement OK)	IF Conv $[1,1]="N" THEN REWIND B$

TABLE A-XIX

DATA FILES AND PROGRAMS USED FOR FOURIER ANALYSIS

Data/Program	Where Stored (Note 1)	
15000 RPM (DATA)	"TERRY2"	(Raw Form - 256 Data Points)
	"AVG2"	(Averaged Form - 256 Data Points) See Note 2
19000 RPM (DATA)	"TERRY1"	(Raw Form - 256 Data Points)
	"AVG1"	(Averaged Form - 256 Data Points) See Note 2
40 Point Power Correlation Data	"TERRY3"	(Before referring)
FIXER (Program to take out the 'DC' components from raw RPM data and store on a different data file)	TPL Library Tape #1	

Note 1: All data files listed in this table are stored on TPL Library #1 Tape (Not to be confused with the H.P. Library tapes.)

Note 2: The data could only be analyzed in powers of 2; therefore all 359 points could not be used and only the first 256 points were analyzed on each RPM data set.

TABLE A-XX

RAW DATA ANOMALIES

Run	Point	Pressure Port	Action
13	1	8	Deleted A(8) from line 1080 in TTR1B for points 1 and 8
13	8	8	
15	2-8	ΔP_{noz} (see Note 1)	Used point 1 value for all points in line 1090 of TTR1B

Note 1: ΔP_{noz} is recorded on channel 27 through scanner number 1 (see Appendix B).

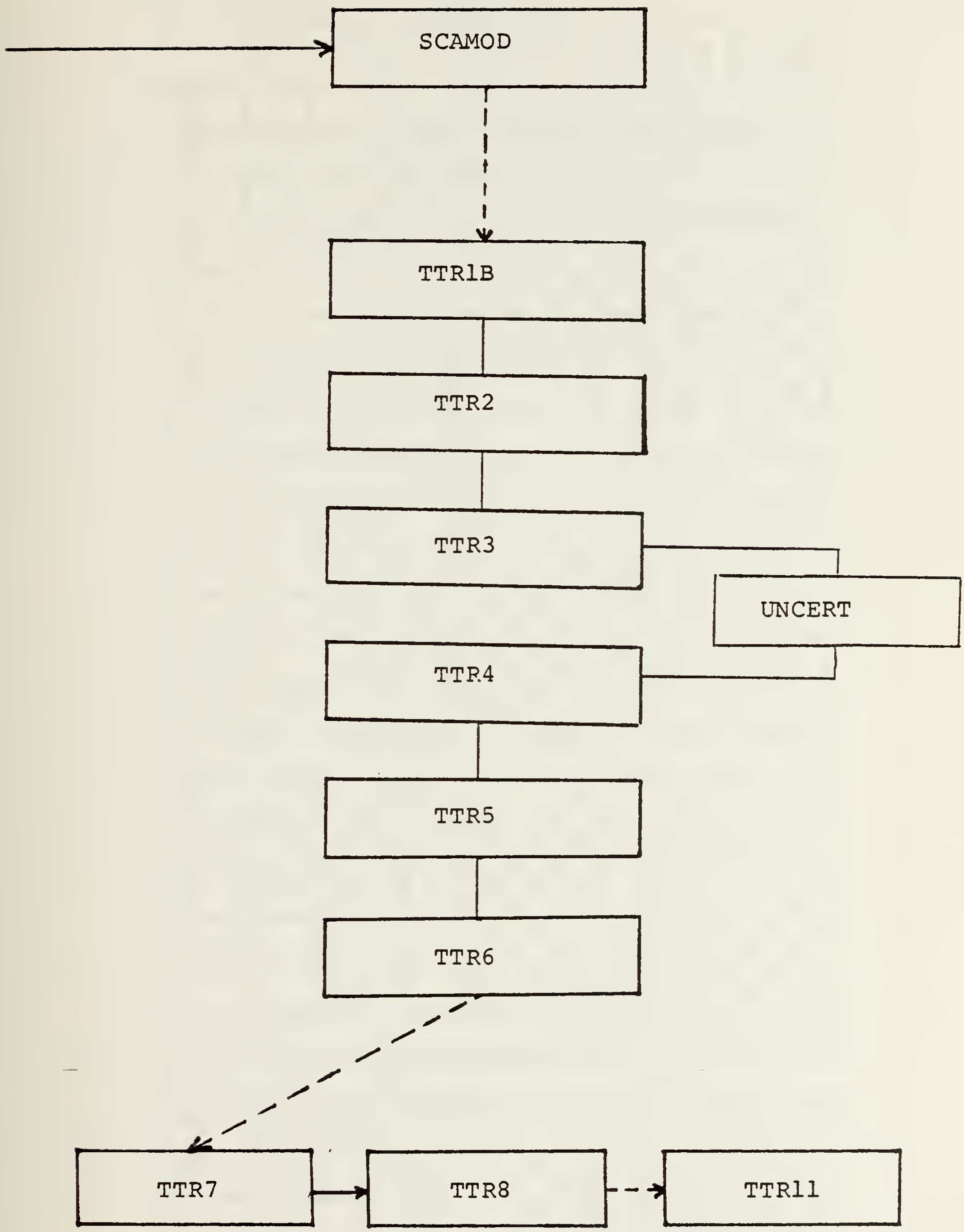


FIGURE A-1. Acquisition, Reduction and Processing Sequence

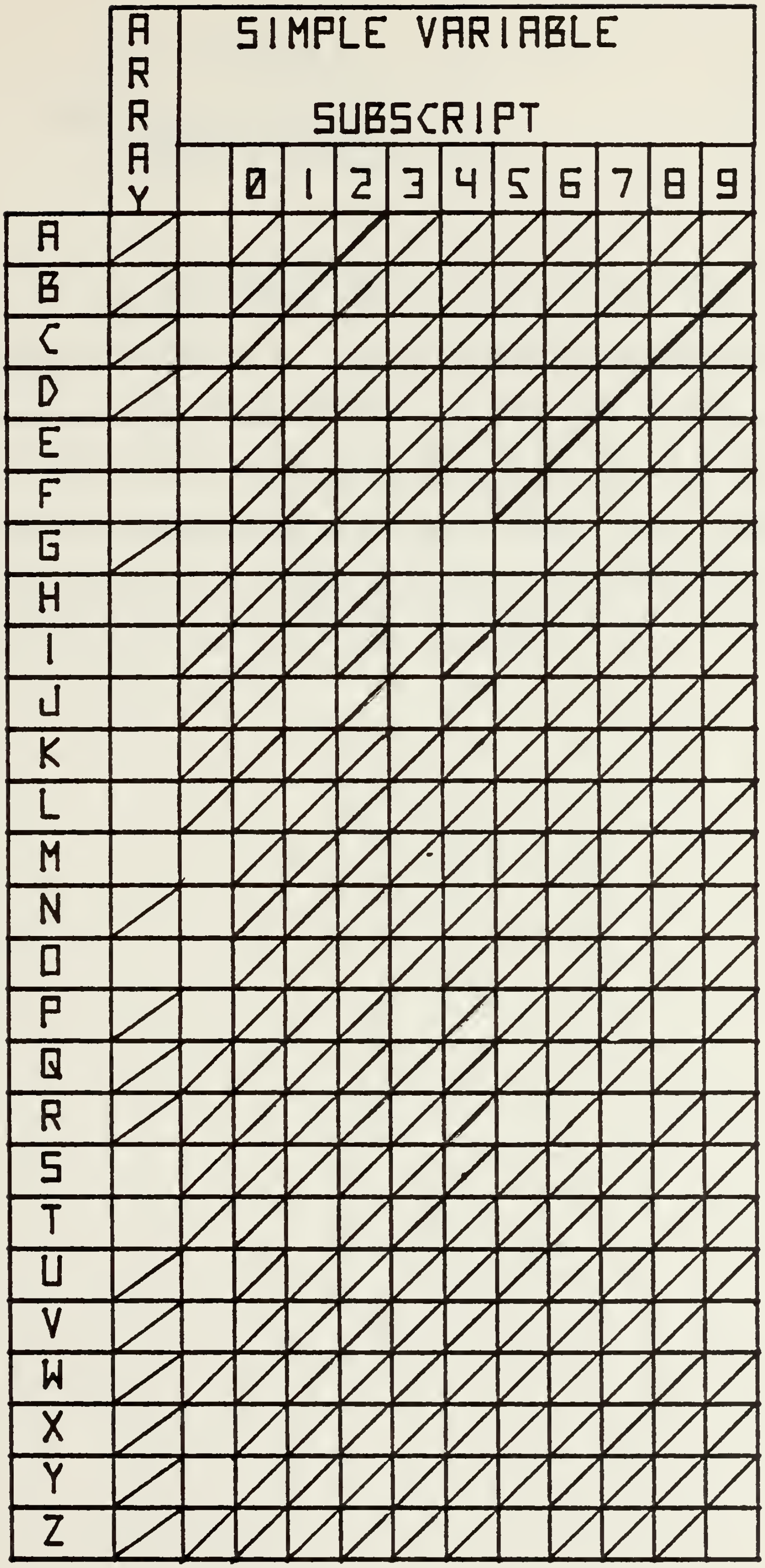


FIGURE A-2. ARRAYS AND VARIABLES USED

APPENDIX B

TEST RIG MEASUREMENTS AND SCALING FACTORS

The test rig measurements were obtained using the test instrumentation of Figure 5. The 46 recorded scanivalve ports and corresponding quantities are given in Table B-I. The channel numbers and corresponding quantities for the 15 other recorded parameters are also listed. The scaling factors applied to the raw data voltages to obtain the proper engineering units are given in Table B-II.

TABLE B-I

TEST RIG MEASUREMENTS

Pressures

Scanivalve Port Number (Scanner 1)	Quantity
1	Atmospheric
2	Calibration Reference
3	Flow Nozzle (upstream flange)
4	Flow Nozzle (downstream flange)
5	Labyrinth Plenum (Fig. 2)
6	Stator Total Inlet (Fig. 3)
7	"
8	"
9	"
10	"
11	Hood
12	Stator Tap #1 (Fig. 7)
13	Stator Tap #2 (Fig. 7)
14	Stator Tap #3 (Fig. 7)
15	Stator Tap #4 (Fig. 7
16	Stator Tap #5 (Fig. 7)
17	Stator Tap #6 (Fig. 7
18	Stator Tap #7 (Fig. 7)
19	Stator Tap #8 (Fig. 7)
20	Stator Tap #9 (Fig. 7)
21	Stator Exit Hub (Fig. 3)
22	Stator Tip (above Tap #8)
23	Stator Tip (above Tap #9)
24	Stator Exit Tip (Fig. 3) (See Note 1)
25	Atmospheric (spare)
26	Calibration Reference (spare)
27	Labyrinth (spare)
28	Stator Inlet Static
29 through 46	Rotor Shroud (spaced at 1 inch between centers along shroud inclined face

TABLE B-I (Cont'd)

Other Channels

Scanner Number	Scanner Channel	Quantity
2	00	Air supply temperature
	01	Flow nozzle temperature
	02	Inlet plenum temperature
	03	Closure volume temperature
	04	Stator total inlet temperature
	05	Turbine outlet total temperature
	06	Labyrinth temperature
1	16	RPM
	20	Stator axial force
	21	Closure plate force
	23	Dynamometer torque
	24	Stator torque
	25	Atmospheric pressure
	26	Flow nozzle pressure
	27	Flow nozzle ΔP

Note 1: This channel is sampled 30 times and averaged prior to storage to reduce unsteadiness.

TABLE B-II

SCALING FACTORS

Parameter	Channel Number	Scaling Factor
Pressure (all scanivalve ports)	1 (Scanner #1)	Conversion to in Hg x 1000
Temperatures	00-06 (Scanner #2)	Polynomial regression formula to °F + 460 to °R
RPM	16 (Scanner #1)	x 2
Axial Force	20 (Scanner #1)	x 10^5
Closure Force	21 (Scanner #1)	x 10^4
Dynamometer Torque	23 (Scanner #1)	x 10^5
Stator Torque	24 (Scanner #1)	x 10^5
Atmospheric Pressure	25 (Scanner #1)	x 10^4
Flow Nozzle Pressure	26 (Scanner #1)	x 10^4
Flow Nozzle ΔP	27 (Scanner #1)	x 10^4

APPENDIX C

UNCERTAINTY ANALYSIS

An uncertainty analysis was conducted on four key interstage parameters, i.e., stator exit pressure ratio (P_1/Pt_o), resultant axial force (RAF), stator loss coefficient (ζ_S), and rotor loss coefficient (ζ_R). The analysis was done in accordance with the principles contained in Ref. (16). The following formulas were used repeatedly to develop the propagation formulas for each intermediate parameter of interest:

Note: "U" denotes uncertainty interval throughout this appendix.

$$\text{Desired form:} \quad \frac{U_R}{R} = \left[\left(\frac{\partial \ln V_i}{\partial \ln R}\,\frac{U_{V_i}}{V_i}\right)^2 + \left(\frac{\partial \ln w_i}{\partial \ln R}\,\frac{U_{w_i}}{w_i}\right)^2\right]^{1/2}$$

where v_i and w_i are independent variables and $R = f(v_i, w_i)$.

1. If $R = x \pm y$ then

$$\frac{\partial \ln x}{\partial \ln R} = \frac{x}{x \pm y} \quad \text{and} \quad \frac{\partial \ln y}{\partial \ln R} = \frac{-y}{x \pm y}$$

and

$$U_R = [(U_x)^2 + (\pm U_y)^2]^{1/2}$$

2. If $R = 1 - y^n$, then

$$\frac{U_R}{R} = \frac{ny^n}{1 - y^n} \frac{U_y}{y}$$

3. If $R = x + y^n$, then

$$\frac{U_R}{R} = [(\frac{x}{x + y^n} \cdot \frac{U_x}{x})^2 + (\frac{ny^n}{x + y^n} \cdot \frac{U_y}{y})^2]^{1/2}$$

4. If $R = xy^n + z^m$, then

$$\frac{U_R}{R} = [(\frac{xy^n}{R} \cdot \frac{U_x}{x})^2 + (\frac{nxy^n}{R} \cdot \frac{U_y}{y})^2 + (\frac{mz^m}{R} \cdot \frac{U_z}{z})^2]^{1/2}$$

5. If $R = V^n$, then

$$\frac{U_R}{R} = v \frac{U_V}{V}$$

6. If $R = ax \pm by$, then

$$U_R = [(a\ U_x)^2 + (b\ U_y)^2]^{1/2}$$

The following development is divided into five sections. In each of four sections, one reduced parameter uncertainty is calculated. A simplified analysis section follows.

Table C-I contains the definition of terms used in the analysis. Symbols used in this appendix are consistent with those used in the reduction program in Appendix A. The

assumed uncertainty intervals in the raw data parameters of interest are given in Table C-II and are consistent with those given in Ref. 1. The point chosen for analysis was run 10 point 1. Pertinent raw data, and intermediate calculation data are given in Table C-III. The uncertainty approximation formulas developed here are summarized in Table C-IV.

C.1 RESULTANT AXIAL FORCE (R2) UNCERTAINTY

Using Eqn C(4) in Reference 1, the resultant axial force is given by

$$R2 = F4 + F5 + 0.491159(F3 - F2 - F\emptyset')$$

where

$$F\emptyset' = F\emptyset + F1 + A8 + A9 + B5 + B6 + B7$$

and

$$F\emptyset = N8(0.25) + N9(0.50) + O1(0.50)$$

The uncertainty in R2 is then calculated by first calculating the uncertainty in each of the terms in the above expressions. These calculations follow:

$$U_{F\emptyset} = [(0.25 \times .05)^2 + (.5 \times .04)^2 + (.5 \times .04)^2]^{1/2}$$

$$= .03$$

since,

$$F1 = 0.51(S3 + S4 + S5)$$

$$U_{F1} = 0.51[(U_{S3})^2 + (U_{S4})^2 + (U_{S5})^2]^{1/2}$$

$$= 0.51[3(.04)^2]^{1/2}$$

$$= .0353$$

and since

$$A8 = 0.51(S6 + S7 + S8)$$

$$U_{A8} = 0.51[(U_{S6})^2 + (U_{S7})^2 + (U_{S8})^2]^{1/2}$$

$$= 0.51[3(.04)^2]^{1/2}$$

$$= .0353$$

Also, since

$$A9 = 0.52[S9 + N\emptyset + N1]$$

$$U_{A9} = [(U_{S9})^2 + (U_{N\emptyset})^2 + (U_{N1})^2]^{1/2}$$

$$= 0.52[3(.04)^2]^{1/2}$$

$$= .036$$

Similarly,

$$B5 = 0.52N2 + 0.52N3 + 0.53N4$$

$$U_{B5} = [(0.52\,U_{N2})^2 + (0.52\,U_{N3})^2 + (0.53\,U_{N4})^2]^{1/2}$$

$$= [(0.52 \times .04)^2 + (0.52 \times .04)^2 + (0.53 \times .04)^2]^{1/2}$$

$$= .03625$$

$$B6 = 0.71\ N5 + 4.80999(N6 + N7)$$

$$U_{B6} = [(0.71\ U_{N5})^2 + (4.80999\ U_{N6})^2 + (4.8099\ U_{N7})^2]^{1/2}$$

$$= [(0.71 \times .04)^2 + (4.80999 \times .04)^2 \times 2]^{1/2}$$

$$= .2736$$

<u>Note here the order of magnitude difference in the uncertainties of N6 and N7 compared with the other parameters.</u>

Continuing,

$$B7 = 1.897 \times Q4$$

$$U_{B7} = 1.897\ U_{Q4} = .07588$$

Therefore,

$$U_{F\emptyset'} = [(U_{F\emptyset})^2 + (U_{F1})^2 + (U_{A8})^2 + (U_{A9})^2 + (U_{B5})^2 + (U_{B6})^2 + (U_{B7})^2]^{1/2}$$

$$= [(.03)^2 + (.0353)^2 + (.0353)^2 + (.036)^2 + (.03625)^2 + (.2736)^2 + (.07588)^2]^{1/2}$$

$$= .2943$$

Similarly,

$$F2 = 47.66118069 \times R8$$

$$U_{F2} = 47.66118069\ U_{R8} = 47.66118069 \times .04$$

$$= 1.9064$$

$$F3 = 82.51589456 \times Q3$$

$$U_{F3} = 82.51589456\ U_{Q3}$$

$$= 82.51589456 \times .04$$

$$= 3.3006$$

Finally,

$$U_{R2} = [(U_{F4})^2 + (U_{F5})^2 + (.491159\ U_{F3})^2 + (-.491159\ U_{F2})^2 + (-.491159\ U_{F\emptyset'})^2]^{1/2}$$

$$U_{R2} = [(.48)^2 + (.48)^2 + (.491159 \times 3.3006)^2 + (-.491159 \times 1.9064)^2 + (-.491159 \times .2943)^2]^{1/2}$$

$$= \underline{1.9966 \text{ lbf}}$$

<u>Note here the predominant effects of Q3 and R8, i.e., the hood pressure and stator exit pressure "hub #3" respectively</u>.

Therefore, the potential % error in the resultant axial force is equal to

$$\frac{U_{R2}}{R2} \times 100\% = \frac{1.9966}{130.79} \times 100\% = \underline{1.53\%}$$

C.2 PRESSURE RATIO (P2) UNCERTAINTY

Since Q1 is the average of five pressures (Ports 6- 10, see Appendix B),

$$U_{Q1} = .2[5(U_{\text{each channel}})^2]^{1/2} = .2\sqrt{5}(.04)$$

$$= .0179 \text{ in Hg}$$

$$Q2 = \frac{Q1}{29.92}$$

Therefore,

$$\frac{U_{Q2}}{Q2} = \frac{U_{Q1}}{Q1} = \frac{.0179}{59.622} = .0003$$

Similarly,

$$T3 = \left(\frac{T2}{518.7}\right)^{1/2}$$

$$\frac{U_{T3}}{T3} = \frac{1}{2}\frac{U_{T2}}{T2} = \frac{1}{2}\frac{.5}{636.40\ R} = .00039$$

$$W\emptyset = \frac{\dot{W}_{ref}\ \ Q2}{T3}$$

$$\frac{U_{W\emptyset}}{W\emptyset} = \left[\left(\frac{U_{\dot{W}ref}}{\dot{W}_{ref}}\right)^2 + \left(\frac{U_{Q2}}{Q2}\right)^2 + \left(-\frac{U_{T3}}{T3}\right)^2\right]^{1/2}$$

From this point on, $\dot{W}_{ref}$ (referred flow rate) is assumed to be constant at 1.02 lbm/sec. Hence

$$\frac{U_{W\emptyset}}{W\emptyset} = [(-.00039)^2 + (.0003)^2]^{1/2} = .00049$$

and

$$\frac{U_{W4}}{W4} = \frac{U_{W\emptyset}}{W\emptyset} = .00049.$$

Continuing,

$$V1 = 109.62 \times SQR(T2)$$

$$\frac{U_{V1}}{V1} = \frac{1}{2}\frac{U_{T2}}{T2} = .00039$$

$$\frac{U_{V7}}{V7} = \left[\left(\frac{U_{W4}}{W4}\right)^2 + \left(\frac{U_{V1}}{V1}\right)^2 + \left(-\frac{U_{Q1}}{Q1}\right)^2\right]^{1/2}$$

$$\frac{U_{V7}}{V7} = [(.00049)^2 + (.00039)^2 + (-.0003)^2]^{1/2}$$

$$= .0007$$

$$V\emptyset = \frac{M6}{W4 \times 4.18375}$$

$$\frac{U_{V\emptyset}}{V\emptyset} = [(\frac{U_{M6}}{M6})^2 + (-\frac{U_{W4}}{W4})^2]^{1/2}$$

$$= [(\frac{.99}{361.02})^2 + (-.00049)^2]^{1/2}$$

$$= .0027864$$

$$X\emptyset = \frac{V\emptyset}{V1}$$

$$\frac{U_{X\emptyset}}{X\emptyset} = [(\frac{U_{V\emptyset}}{V\emptyset})^2 + (-\frac{U_{V1}}{V1})^2]^{1/2}$$

$$= [(.0027864)^2 + (-.00039)^2]^{1/2}$$

$$= .00281$$

$$Z\emptyset = \frac{0.402}{2.402}[(V7)^2 \times (1 - (X\emptyset)^2) - .018(\frac{R2}{Q1})^2]$$

Let

$$L = 1 - (X\emptyset)^2.$$

Since $X\emptyset = .5435$ (using data for this point),

$$\frac{U_L}{L} = \frac{2(X\emptyset)^2}{1 - (X\emptyset)^2} \times \frac{U_{X\emptyset}}{X\emptyset} = \frac{2(.5435)^2}{1 - (.5435)^2}(.00281) = .00236$$

Let $A = (V7)^2 L$, then

$$\frac{U_A}{A} = [(2 \frac{U_{V7}}{V7})^2 + (\frac{U_L}{L})^2]^{1/2}$$

$$= [(2 \times .0007)^2 + (.00236)^2]^{1/2}$$

$$= .00274$$

Let $B = .018(\frac{R2}{Q1})^2$. Then,

$$\frac{U_B}{B} = 2[[\frac{U_{R2}}{R2}]^2 + [- \frac{U_{Q1}}{Q1}]^2]^{1/2}$$

$$= 2[(.0153)^2 + (-.0003)^2]^{1/2}$$

$$= .0305$$

Therefore,

$$Z\emptyset = .167(A - B)$$

$$\frac{U_{Z\emptyset}}{Z\emptyset} = [(\frac{.167A}{A - B} \frac{U_A}{A})^2 + (- \frac{.167B}{A - B} \frac{U_B}{B})^2]^{1/2}$$

From the definitions of A and B,

$$A = (V7)^2 L \qquad \text{and} \qquad B = .018(\frac{R2}{Q1})^2$$

For this point,

$$V7 = .3571$$

$$L = 1 - (X\emptyset)^2 = .7045$$

$$R2 = 130.79$$

$$Q1 = 59.622$$

Hence,

$$A = (.3571)^2(.7045) = .0898$$

$$B = .018\left(\frac{130.79}{59.622}\right)^2 = .0865$$

$$\frac{U_{Z\emptyset}}{Z\emptyset} = \left[\left(\frac{.167(.0898)}{.0898 - .0865} \times .00274\right)^2 + \left(\frac{-.167(.0865)}{.0898 - .0865}\right) \times .0305)^2\right]^{1/2}$$

$$= .1353$$

<u>Note here again, the predominant effect is from R2 in the uncertainty error of Z∅.</u> Continuing,

$$B\emptyset = .0558 \frac{R2}{Q1}$$

$$\frac{U_{B\emptyset}}{B\emptyset} = \left[\left(\frac{U_{R2}}{R2}\right)^2 + \left(-\frac{U_{Q1}}{Q1}\right)^2\right]^{1/2}$$

$$= [(.0153)^2 + (.0003)^2]^{1/2} = .0153$$

Now

$$P2 = B\emptyset + SQR((B\emptyset)^2 - Z\emptyset)$$

Let $C = (B\emptyset)^2 - Z\emptyset$, then

$$\frac{U_C}{C} = \left[\left(\frac{2(B\emptyset)^2}{(B\emptyset)^2 - Z\emptyset} \frac{U_{B\emptyset}}{B\emptyset}\right)^2 + \left(- \frac{Z\emptyset}{(B\emptyset)^2 - Z\emptyset} \frac{U_{Z\emptyset}}{Z\emptyset}\right)^2\right]^{1/2}$$

For this point,

$$B\emptyset = .1224$$

$$Z\emptyset = 5.49267 \times 10^{-4}$$

therefore

$$\frac{U_C}{C} = \left[\left(\frac{2(.1224)^2}{(.1224)^2 - (5.49 \times 10^{-4})}(.0153)\right)^2\right.$$

$$\left. + \left(- \frac{5.49267 \times 10^{-4}}{(.1224)^2 - (5.49 \times 10^{-4})}(.1353)\right)^2\right]^{1/2}$$

$$= .0321$$

Note here the predominant effect of the $B\emptyset$ term which in turn is due almost exclusively to the P2 terms. Continuing,

$$P2 = B\emptyset + \sqrt{C}$$

$$\frac{U_{P2}}{P2} = \left[\left(\frac{B\emptyset}{B\emptyset + SQR(C)} \frac{U_{B\emptyset}}{B\emptyset}\right)^2 + \left(\frac{\frac{1}{2} C^{1/2}}{B\emptyset + SQR(C)} \frac{U_C}{C}\right)^2\right]^{1/2}$$

Here,

$$C = (.1224)^2 - (5.49 \times 10^{-4}) = .01445$$

$$\sqrt{C} = .202.$$

Therefore,

$$\frac{U_{P2}}{P2} = [(\frac{.1224}{(.1224) + .1202}(.0153))^2 + (\frac{\frac{1}{2}(.1202)}{.1224 + .1202}(.0321))^2]^{1/2}$$

$$= .0111$$

<u>Note the almost total influence of R2 over the uncertainty in P2.</u>

C3. STATOR LOSS COEFFICIENT (ζ_S) UNCERTAINTY

The calculation of the uncertainty in stator loss coefficient requires first the calculation of the uncertainties in the intermediate variables defined in the data reduction program. In the calculation of the axial component of the velocity,

$$X1' = 3.487562189 \frac{P2}{V7}$$

$$\frac{U_{X1'}}{X1'} = [(\frac{U_{P2}}{P2})^2 + (-\frac{U_{V7}}{V7})^2]^{1/2}$$

$$= [(.0111)^2 + (-.0007)^2] = .0111$$

Then

$$X1 = - X1' + SQR((X1')^2 - (X\emptyset)^2 + 1)$$

Let $D = (X1')^2 - (X\emptyset)^2 + 1$. Then,

$$\frac{U_D}{D} = [(\frac{2(X1')^2}{(X1')^2 - (X\emptyset)^2 + 1}(\frac{U_{X1'}}{X1'}))^2 + (\frac{2(X\emptyset)^2}{(X1')^2 - (X\emptyset)^2 + 1}(\frac{U_{X\emptyset}}{X\emptyset}))^2]^{1/2}$$

For this point

$$X1' = 3.487(\frac{.2427}{.3571}) = 2.37$$

$$X\emptyset = .5436$$

Therefore,

$$\frac{U_D}{D} = [(\frac{2(2.37)^2}{(2.37)^2 - (.5436)^2 + 1}(.0111))^2$$

$$+ (-\frac{2(.5436)^2}{(2.37)^2 - (.5436)^2 + 1}(.00281))^2]^{1/2}$$

$$= .01972$$

<u>The predominant effect here is from P2 and therefore from R2.</u>

Since X1 = SQR(D) - X1',

$$\frac{U_{X1}}{X1} = [(\frac{\frac{1}{2} D^{1/2}}{D^{1/2} - X1'} \frac{U_D}{D})^2 + (-\frac{X1'}{D^{1/2} - X1'} \frac{U_{X1'}}{X1'})^2]^{1/2}$$

For this point,

$$D = (2.37)^2 - (.5436)^2 + 1 = 6.323$$

so that

$$\frac{U_{X1}}{X1} = [(\frac{\frac{1}{2}(6.323)^{1/2}}{(6.323)^{1/2} - (2.37)} (.01972))^2$$

$$+ (-\frac{2.37}{(6.323)^{1/2} - (2.37)} (.0111))^2]^{1/2}$$

$$= .2506$$

<u>Again, the prime contributors to the uncertainty in the axial component of velocity is due to P2, and therefore to R2.</u> Note also the high errors introduced through taking differences between calculated quantities as in the denominators of the bracketed terms in the X1 uncertainty formula. Continuing,

$$X2 = SQR((XØ)^2 + (X1)^2)$$

Let

$$E = (XØ)^2 + (X1)^2 \rightarrow \frac{U_E}{E} = [(\frac{2(XØ)^2}{(XØ)^2 + (X1)^2} \frac{U_{XØ}}{XØ})^2$$

$$+ (\frac{2(X1)^2}{(XØ)^2 + (X1)^2} \frac{U_{X1}}{X1})^2]^{1/2}$$

For this point,

$$X1 = .144224719$$

Therefore,

$$\frac{U_E}{E} = [(\frac{2(.5436)^2}{(.5436)^2 + (.1442)^2}(.00281))^2$$

$$+ (\frac{2(.1442)^2}{(.5436)^2 + (.1442)^2}(.2506))^2]^{1/2}$$

$$= .03338$$

$$X2 = \text{SQR } E$$

$$\frac{U_{X2}}{X2} = \frac{1}{2}\,\frac{U_E}{E} = .0167$$

<u>The predominant effect is from X1, and therefore again from R2 through its effect on P2</u>. Finally,

$$Z1 = \zeta_S = 1 - \frac{(X2)^2}{1 - (P2)^{.287}}$$

Let

$$G = 1 - P2^{.287}$$

Then

$$\frac{U_G}{G} = [(-\frac{.287(P2)^{.287}}{1 - (P2)^{.287}} \times \frac{U_{P2}}{P2})^2]^{1/2}$$

$$= [(-\frac{.287(.2427)^{.287}}{1 - (.2427)^{.287}} \times .0111)^2]^{1/2}$$

$$= .00634$$

Let $H = \frac{(X2)^2}{G}$. Then

$$\frac{U_H}{H} = [(2\frac{U_{X2}}{X2})^2 + (-\frac{U_G}{G})^2]^{1/2}$$

$$= [(2 \times .0167)^2 + (-.00634)^2]^{1/2}$$

$$= .03398$$

<u>Note the predominant effect of the X2 term and, through X1 and P2, the overriding importance of the uncertainty in R2.</u> Continuing,

$$Z1 = 1 - H$$

$$\frac{U_{Z1}}{Z1} = [(-\frac{H}{1-H}\frac{U_H}{H})^2]^{1/2}$$

$$H = \frac{(X2)^2}{G} = \frac{(X2)^2}{1-(P2)^{.287}}$$

For this point

$$X2 = .562373442$$

Therefore,

$$H = \frac{(.562)^2}{1-(.2427)^{.287}} = .9478$$

and

$$\frac{U_{Z1}}{Z1} = [(-\frac{.9478}{1 - .9478} \times .03398)^2]^{1/2}$$

$$= .617$$

As can be seen, the uncertainty in the axial force (R2) is the major contributor to the uncertainty in the calculated interstage pressure and consequently to the stator loss coefficient. The uncertainty in R2, however, is in turn determined primarily by the uncertainties in two key pressure measurements. The measurements corresponding to computer program parameters Q3 and R8 are those on ports 11 and 21 which are connected to the hood and to the closure plate volume.

C.4. ROTOR LOSS COEFFICIENT (ζ_R) UNCERTAINTY

The uncertainty in the rotor torque is obtained using the measurement uncertainty:

$$\frac{U_{M5}}{M5} = \frac{.427 \text{ in-lbf}}{446.90} = 0.000955$$

Then,

$$X4 = .984\, X\emptyset - .235 \frac{M5}{W4(V1)}$$

Let

$$I = \frac{M5}{W4(V1)}$$

$$\frac{U_I}{I} = [(\frac{U_{M5}}{M5})^2 + (-\frac{U_{W4}}{W4})^2 + (-\frac{U_{V1}}{V1})^2]^{1/2}$$

$$= [(0.00095)^2 + (-.00049)^2 + (-.00039)^2]^{1/2}$$

$$= .00114$$

Therefore,

$$\frac{U_{X4}}{X4} = [(\frac{.984X\emptyset}{.984X\emptyset - .235I}(\frac{U_{X\emptyset}}{X\emptyset}))^2 + (\frac{-.235I}{.984X\emptyset - .235I}(\frac{U_I}{I}))^2]^{1/2}$$

$$I = \frac{M5}{W4(V1)} = \frac{446.9}{(.0574)(2765.36)} = 2.815$$

Let

$$J = U3(X\emptyset) - U4(X4)$$

and

$$K = U3(X\emptyset)$$

$$L = U4(X4)$$

$$\frac{U_K}{K} = [(\frac{U_{U3}}{U3})^2 + (\frac{U_{X\emptyset}}{X\emptyset})^2]^{1/2}$$

$$= [(.0158)^2 + (.00281)^2]^{1/2} = .0161$$

$$\frac{U_L}{L} = [(\frac{U_{U4}}{U4})^2 + (\frac{U_{X4}}{X4})^2]^{1/2}$$

$$= [(.0158)^2 + (.00696)^2]^{1/2} = .0172$$

Therefore,

$$J = K - L$$

giving

$$\frac{U_J}{J} = [(\frac{K}{K-L}\frac{U_K}{K})^2 + (\frac{-L}{K-L}\frac{U_L}{L})^2]^{1/2}$$

$$K = \frac{U3(X\emptyset)}{V1} = \frac{.0365(11077)(.5435)}{2765.362559} = .07949$$

$$L = U4(X4) = \frac{.0371(11077)(-.1272)}{2765} = -.0189$$

$$X4 = .984(.5536) - .235(2.815) = -.1272$$

$$\frac{U_J}{J} = [(\frac{.07949}{.07949 - (-.0189)}(.0161))^2 + (\frac{-(-.0189)}{.07949 - (-.0189)}(.0172))^2]^{1/2}$$

$$= .01338$$

Let

$$M = 1 - (X4)^2 = 1 - (-.1272)^2 = .9838$$

therefore,

$$\frac{U_M}{M} = \frac{2(X4)^2}{1-(X4)^2}\frac{U_{X4}}{X4} = \frac{2(-.1272)^2}{1-(-.1272)^2}(.00696)$$

$$= .000229$$

$$Z2 = M - 2(J)$$

$$J = K - L = .07949 - (-.0189) = .0984$$

$$\frac{U_{Z2}}{Z2} = [(\frac{M}{M - 2J}\frac{U}{})^2 + (\frac{-2J}{M - 2J}\frac{U_J}{J})^2]^{1/2}$$

$$= [(\frac{.9838}{.9838 - 2(.0984)}(.000229))^2$$

$$+ (\frac{-2(.0984)}{.9838 - 2(.0984)}(.01338))^2]^{1/2}$$

$$= .00336$$

$$\frac{U_{X4}}{X4} = [\frac{.984(.5435)}{.984(.5435) - .235(2.815)}(.00281))^2$$

$$+ (\frac{-.235(2.815)}{.984(.5435) - .235(2.815)}(.00114))^2]^{1/2}$$

$$= .00696$$

$$Z2 = (1 - (X4)^2) - 2(U3)(X\emptyset) - (U4)(X4)$$

$$U3 = \frac{U1}{V1}$$

$$U1 = .0365(N)$$

$$\frac{U_{U1}}{U1} = \frac{U_N}{N} = \frac{175}{11\emptyset77} = .01579$$

Therefore,

$$\frac{U_{U3}}{U3} = [(\frac{U_{U1}}{U1})^2 + (-\frac{U_{V1}}{V1})^2]^{1/2} = [(.01579)^2 + (-.00039)^2]^{1/2}$$

$$= .0158$$

Now,

$$U4 = \frac{U2}{V1},$$

where

$$U2 = .0371(N)$$

Therefore,

$$\frac{U_{U2}}{U2} = \frac{U_{U1}}{U1} = .01579$$

and

$$\frac{U_{U4}}{U4} = \frac{U_{U3}}{U3} = .0158$$

$$P9 = \frac{S9 + Q3}{2}$$

$$\frac{U_{P9}}{P9} = [(\frac{0.5(S9)}{S9 + Q3} \frac{U_{S9}}{S9})^2 + ((\frac{0.5\ Q3}{S9 + Q3}) \frac{U_{Q3}}{Q3})^2]^{1/2}$$

$$= [(\frac{0.5(.04)}{34.2929})^2 + (\frac{0.5(.04)}{34.2929})^2]^{1/2}$$

$$= .0008247$$

$$S9 = 17.0582$$

$$\frac{U_{S9}}{S9} = \frac{.04}{17.0582} = .00234$$

$$Q3 = 17.2347$$

$$\frac{U_{Q3}}{Q3} = \frac{.04}{17.2347} = .00232$$

$$B1 = 38.78\left(\frac{P9}{W4\,(V1)}\right)$$

and

$$P9 = 17.14645$$

therefore,

$$\frac{U_{B1}}{B1} = \left[\left(\frac{U_{P9}}{P9}\right)^2 + \left(-\frac{U_{W4}}{W4}\right)^2 + \left(-\frac{U_{V1}}{V1}\right)^2\right]^{1/2}$$

$$= \left[(.0008247)^2 + (-.00049)^2 + (-.00039)^2\right]^{1/2}$$

$$= .0010356$$

$$X5 = -B1 + SQR((B1)^2 + Z2)$$

Let

$$N = (B1)^2 + Z2$$

and since

$$B1 = 4.188649456$$

$$Z2 = .78699067$$

$$\frac{U_N}{N} = [(\frac{2(B1)^2}{(B1)^2 + Z2}\ \frac{U_{B1}}{B1})^2 + (\frac{Z2}{(B1)^2 + Z2}\ \frac{U_{Z2}}{Z2})^2]^{1/2}$$

$$= [(\frac{2(4.188)^2}{(4.188)^2 + (.78699)}(.0010356))^2$$

$$+ (\frac{.78699}{(4.188)^2 + (.78699)}(.00336))^2]^{1/2}$$

$$= .00198$$

Therefore,

$$X5 = -B1 + \sqrt{N}$$

and

$$N = 18.33177494$$

$$\frac{U_{X5}}{X5} = [(\frac{0.5\ SQR(N)}{-B1 + SQR(N)}\ \frac{U_N}{N})^2 + (\frac{-B1}{-B1 + SQR(N)}\ \frac{U_{B1}}{B1})^2]^{1/2}$$

$$= [(\frac{0.5(18.33)^{1/2}}{-4.188 + (18.33)^{1/2}}(.00198))^2$$

$$+ (\frac{-4.188}{-4.188 + (18.33)^{1/2}}(.00104))^2]^{1/2}$$

$$= .0653122238$$

<u>Note that it is the differences in the denominators of each of the terms in the above equation which give rise to the large resultant uncertainty</u>. Continuing,

$$L\emptyset = (X5)^2 + (X4 - U4)^2$$

Let

$$O = X4 - U4$$

Here,

$$U4 = .14856054$$

Therefore,

$$\frac{U_O}{O} = [(\frac{X4}{X4 - U4}\ \frac{U_{X4}}{X4})^2 + (\frac{-U4}{X4 - U4}\ \frac{U_{U_4}}{U4})^2]^{1/2}$$

$$= [(\frac{-.1273}{-.1273 - .1486}(.00696))^2$$

$$+ (\frac{-.1486}{-.1273 - .1486}(.0158))^2]^{1/2}$$

$$= .009096$$

$$L\emptyset = (X5)^2 + (O)^2$$

and here

$$X5 = .092912751$$

$$O = -.2758526482$$

Therefore,

$$\frac{U_{L\emptyset}}{L\emptyset} = [(\frac{2(X5)^2}{(X5)^2 + (O)^2} \frac{U_{X5}}{X5})^2 + (\frac{2(O)^2}{(X5)^2 + (O)^2} \frac{U_O}{O})^2]^{1/2}$$

$$= [(\frac{2(.0929)^2}{(.0929)^2 + (-.2759)^2}(.0653))^2$$

$$+ (\frac{2(-.2759)^2}{(.0929)^2 + (-.2759)^2}(.00909))^2]^{1/2}$$

$$= .021073843$$

$$L1 = (1 - (X2)^2)\ (1 - (\frac{P9}{(P2*Q1)})^{G\emptyset})$$

$$+ (X2)^2 - 2X\emptyset(U3) + (U4)^2$$

Let

$$P = 1 - (X2)^2$$

$$\frac{U_P}{P} = \frac{2(X2)^2}{1 - (X2)^2} \frac{U_{X2}}{X2} = \frac{2(.562373442)^2}{1 - (.562373442)^2}(.0167)$$

$$= .0154492555$$

Let

$$Q = \frac{P9}{P2(Q1)}$$

$$\frac{U_Q}{Q} = [(\frac{U_{P9}}{P9})^2 + (\frac{U_{P2}}{P2})^2 + (\frac{U_{Q1}}{Q1})^2]^{1/2}$$

$$= [(.00082)^2 + (.0111)^2 + (.0003)^2]^{1/2}$$

$$= .0111$$

Note that the P2 term predominates here again. Let

$$R = 1 - Q^{G\emptyset}$$

$$Q = \frac{P9}{P2(Q1)} = \frac{17.14645}{(.242704755)(59.62218)}$$

$$= 1.1849$$

$$\frac{U_R}{R} = \frac{G\emptyset(Q)^{G\emptyset}}{1 - Q^{G\emptyset}} \frac{U_Q}{Q} = \frac{.2867(1.1849)^{.2867}}{1 - (1.1849)^{.2867}}(.0111)$$

$$= .0670486725$$

Let

$$S = P \times R$$

Then

$$\frac{U_S}{S} = [(\frac{U_P}{P})^2 + (\frac{U_R}{R})^2]^{1/2}$$

$$= [(.0154)^2 + (.067048)^2]^{1/2}$$

$$= .0688$$

Let

$$T = (X2)^2$$

$$\frac{U_T}{T} = 2\frac{U_{X2}}{X2} = 2(.0167) = .03339$$

Let

$$V = 2X\emptyset(U3)$$

$$\frac{U_V}{V} = [(\frac{U_{X\emptyset}}{X\emptyset})^2 + (\frac{U_{U3}}{U3})^2]^{1/2}$$

$$= [(.00281)^2 + (.0158)^2]^{1/2}$$

$$= .01605$$

Let

$$W = (U4)^2$$

$$\frac{U_W}{W} = 2\,\frac{U_{U4}}{U4} = 2(.0158) = .0316$$

$$L1 = S + T - V + W$$

$$S = P \times R = (1 - (X2)^2)(1 - (Q)^{G\emptyset}$$

$$= (1 - (.56237373442)^2)(1 - (1.1849)^{.2867})$$

$$= -.034$$

$$T = (X2)^2 = .316$$

$$V = 2(X\emptyset)(U3) = 2(.543565192)(.146240442)$$

$$= .15898$$

$$W = (U4)^2 = (.1485)^2 = .02207$$

Therefore,

$$L1 = .1452648551$$

$$\frac{U_{L1}}{L1} = [(\frac{S}{L1}\frac{U_S}{S})^2 + (\frac{T}{L1}\frac{U_T}{T})^2 + (\frac{-V}{L1}\frac{U_V}{V})^2 + (\frac{W}{L1}\frac{U_W}{W})^2]^{1/2}$$

$$= [(\frac{-.034}{.1453}(.0688))^2 + (\frac{.316}{.1453}(.03339))^2$$

$$+ (\frac{-.15898}{.1453}(.01605))^2 + (\frac{.02207}{.1453}(.0316))^2]^{1/2}$$

$$= .07664$$

The largest effect here is from T, by an order of magnitude. The uncertainty in T alone would have given $\frac{U_{L1}}{L1} = 0.0726$. Therefore $X2 = \sqrt{T}$ is the most important term.

Finally,

$$Z3 = \zeta_R = 1 - \frac{L\emptyset}{L1}$$

Let

$$X = \frac{L\emptyset}{L1}$$

Then

$$\frac{U_X}{X} = [(\frac{U_{L\emptyset}}{L\emptyset})^2 + (-\frac{U_{L1}}{L1})^2]^{1/2}$$

$$= [(.021)^2 + (-.07664)^2]^{1/2} = .07948$$

Here, the effect of the L1 term is overwhelming, which again points to the term X2, and consequently to P2, and R2. Finally,

$$Z3 = \zeta_R = 1 - X$$

where

$$X = \frac{L\emptyset}{L1} = \frac{.084729915}{.145264855} = .5832788323$$

Therefore,

$$\frac{U_{Z3}}{Z3} = \frac{X}{1 - X} \frac{U_X}{X} = \left(\frac{.5833}{1 - .5832}\right)(.07948)$$

$$= \underline{.11125}$$

C.5 SIMPLIFIED ANALYSIS

Given the predominance of the R2 term in both loss coefficient calculations, we can simplify the uncertainty calculation at any point by dropping all uncertainty terms which have a magnitude which is less than one fifth of the R2 uncertainty. With this approximation,

$$U_{R2} = 1.9966 \text{ lbf} \quad \text{(exact for all values of R2)}$$

or

$$\frac{U_{R2}}{R2} = \frac{1.9966}{R2} \quad \text{for a given R,}$$

and the uncertaintiies in Q1, Q2, T3, WØ, W4, V1, V7, VØ and XØ will be considered to be negligible. Under the same approximation,

$$\frac{U_{B\emptyset}}{B\emptyset} = \frac{U_{R2}}{R2}$$

and

$$\frac{U_C}{C} = \frac{2(B\emptyset)^2}{(B\emptyset)^2 - Z\emptyset} \frac{U_{R2}}{R2}$$

where

$$C = (B\emptyset)^2 - Z\emptyset$$

and finally

$$\frac{U_{P2}}{P2} = [(\frac{B\emptyset}{B\emptyset + SQR(C)} \frac{U_{B\emptyset}}{B\emptyset})^2 + (\frac{0.5C^{1/2}}{B\emptyset + SQR(C)} \frac{U_C}{C})^2]^{1/2}$$

where again $B\emptyset$ and $Z\emptyset$ must be obtained from the computer reduction for a given point. Then

$$\frac{U_{X1'}}{X1'} = \frac{U_{P2}}{P2}$$

$$\frac{U_D}{D} = (\frac{2(X1')^2}{(X1')^2 - (X\emptyset)^2 + 1} \frac{U_{X1'}}{X1'})$$

$$= \frac{2(X1')^2}{(X1')^2 - (X\emptyset)^2 + 1} \frac{U_{P2}}{P2}$$

where

$$D = (X1')^2 - (X\emptyset)^2 + 1$$

$$X1' = 3.487562189 \frac{P2}{V7}$$

and XØ, P2 must be again determined from program reduction.

Now

$$\frac{U_{X1}}{X1} = [(\frac{0.5D^{1/2}}{D^{1/2} - X1'} \frac{U_D}{D})^2 + (-\frac{X1'}{D^{1/2} - X1'} \frac{U_{X1'}}{X1'})^2]^{1/2}$$

and

$$\frac{U_{X2}}{X2} = \frac{1}{2}[(\frac{2(X1)^2}{(XØ)^2 + (X1)^2} \frac{U_{X1}}{X1})^2]^{1/2}$$

$$= \frac{(X1)^2}{(XØ)^2 + (X1)^2} \frac{U_{X1}}{X1}$$

and

$$\frac{U_H}{H} = 2 \frac{U_{X2}}{X2}$$

where

$$H = \frac{(X2)^2}{1 - P2^{0.287}}$$

so that

$$\frac{U_{Z1}}{Z1} = \frac{U_{\zeta_S}}{\zeta_S} = \frac{H}{1 - H}(\frac{U_H}{H}).$$

In summary, to calculate the uncertainty in ζ_S at a given point the following parameters must be obtained: R2, Q1, V7, XØ, BØ, ZØ, P2; and X1'. Note: X1' must be calculated as its value is not retained in the current reduction program.

Similarly for the rotor loss coefficient (ζ_R), the prime effect is also through the R2 term. We can obtain a satisfactory approximation by dropping all contributions to the L1 term except X2. This gives

$$\frac{U_{L1}}{L1} = \frac{(X2)^2}{L1}\frac{U_T}{T} = \frac{(X2)^2}{L1}(2)\frac{U_{X2}}{X2}$$

Therefore,

$$\frac{U_X}{X} = \frac{U_{L1}}{L1}$$

and

$$\frac{U_{Z3}}{Z3} = \frac{U_{\zeta_S}}{\zeta_S} = \frac{X}{1 - X}\frac{U_X}{X}$$

where

$$X = \frac{L\emptyset}{L1}$$

Using these approximations for calculating the ζ_S and ζ_R we obtain for the sample point

$$\frac{U_{Z1}}{Z1} = .593 \qquad \text{and} \qquad \frac{U_{Z3}}{Z3} = .0996.$$

Comparison shows that for ζ_S this is only 3% below the exact uncertainty and for ζ_R only 10% below the exact uncertainty. The above approximate formulas have been incorporated into a computer program and used to calculate the uncertainty in R2, P2, Z1, and Z3 for all points in runs 10-15. The program is

called "UNCERT" and is listed as part of Appendix A. A summary of the approximate formulas and required inputs is listed in Table C-IV.

Table C-I

DEFINITION OF TERMS

A8	-	Partial integral of rotor shroud pressure over area
A9	-	Partial integral of rotor shroud pressure over area
BØ	-	Equation (8) from Ref. 7
B1	-	Equation (16) from Ref. 7
B2	-	Beta 1 (β_1) - relative flow angle
B5	-	Partial integral of rotor shroud pressure over area
B6	-	Partial integral of rotor shroud pressure over area
B7	-	Partial integral of rotor shroud pressure over area
FØ'	-	Total axial force-stator
FØ	-	Partial integral of rotor shroud pressure over area
F1	-	Partial integral of rotor shroud pressure over area
F2	-	Closure Plate force
F3	-	Stator exit force
F4	-	Stator axial force - force capsule
F5	-	Closure plate force - force capsule
GØ	-	Ratio of $(\gamma-1)/\gamma = .2857$
LØ	-	Intermediate product in rotor loss coefficient calculation
L1	-	Intermediate product in rotor loss coefficient calculation
M5	-	Rotor torque
M6	-	Stator torque
N	-	Rotor RPM
NØ	-	Rotor shroud static pressure

TABLE C-I (Cont'd)

N1	-	Rotor shroud static pressure
N2	-	Rotor shroud static pressure
N3	-	Rotor shroud static pressure
N4	-	Rotor shroud static pressure
N5	-	Rotor shroud static pressure
N6	-	Rotor shroud static pressure
N7	-	Rotor shroud static pressure
N8	-	Rotor shroud static pressure
N9	-	Rotor shroud static pressure
O1	-	Rotor shroud static pressure
P1	-	Ratio of hood pressure to labrinth pressure
P2	-	Ratio P_l/P_{t_o}
P9	-	Average rotor exit pressure
Q1	-	P
Q2	-	Ratio of P_{t_o}/P_{ref}
Q3	-	Hood pressure
Q4	-	Static pressure at stator tap "tip #3"
R2	-	Resultant force on stator
R8	-	Static pressure at stator tap "hub #3"
S3	-	Rotor shroud static pressure
S4	-	Rotor shroud static pressure
S5	-	Rotor shroud static pressure
S6	-	Rotor shroud static pressure
S7	-	Rotor shroud static pressure
S8	-	Rotor shroud static pressure
S9	-	Rotor shroud static pressure

TABLE C-I (Cont'd)

T2	-	T_{t_o}
T3	-	$\sqrt{\theta}$
U1	-	Intermediate calculation
U2	-	Intermediate calculation
U3	-	Dimensionless rotor velocity
U4	-	Dimensionless rotor velocity
VØ	-	Rotor tangential velocity (V_{U1})
V1	-	Limiting velocity (V_{t_o})
V7	-	Ratio $\overline{P}_1/P_{t_o}$
WØ	-	Total mass flow rate
W4	-	Ratio WØ/g = WØ/32.174
XØ	-	Dimensionless velocity (X_{U1})
X1'	-	Intermediate calculation for obtaining X1
X1	-	Dimensionless velocity (X_{a1})
X2	-	Dimensionless velocity (X_1)
X4	-	Dimensionless velocity (X_{U2})
X5	-	Dimensionless velocity (X_{a2})
X7	-	Blockage factor = 1
X8	-	Intermediate calculation $(\gamma(2(X7) - 1) + 1) = 2.402$
ZØ	-	Intermediate calculation for stator exit pressure
Z1	-	Stator loss coefficient - ζ_S
Z2	-	Intermediate calculation for X_{a2}
Z3	-	Rotor loss Coefficient - ζ_R

<u>Greek letters</u>

β	-	relative flow angle (degrees)
γ	-	ratio of specific heats

TABLE C-I (Cont'd)

ζ	-	loss coefficient
θ	-	ratio of total inlet temperature to standard atmospheric temperature (518.7°R)

<u>Subscripts</u>

a	-	axial direction
ref	-	referred quantity
R	-	rotor
S	-	stator
t (or t_o)	-	total condition
u	-	peripheral component
0	-	stator entrance
1	-	stator exit
2	-	rotor discharge

Table C-II

UNCERTAINTIES ASSIGNED TO RAW DATA PARAMETERS

Temperature		$\pm$ 0.5°F
Pressure		$\pm$ 0.04 in Hg
	or	$\pm$ 0.54 in H_2O
Stator Torque		$\pm$ 0.99 in-lbf
Rotor Torque		$\pm$ 0.427 in-lbf
Force Capsules		$\pm$ 0.48 lbf
RPM		$\pm$ 175 RPM

Table C-III

RAW DATA FOR RUN 10 POINT 1

XØ	=	0.5435	R2	=	130.79 lbf
X1	=	0.1442	T2	=	636.4 °R
X2	=	0.5624	Q1	=	59.622 in Hg
V7	=	0.3571	M5	=	446.90 in-lbf
BØ	=	0.1224	M6	=	361.02 in-lbf
ZØ	=	5.49267×10^{-4}	F4	=	-121.87 lbf
B1	=	4.1886	F5	=	5.90 lbf
Z2	=	0.7870	N	=	11Ø77 RPM
X5	=	.0929			
P9	=	17.14645 in Hg			
P2	=	0.2427			

Table C-IV

UNCERTAINTY APPROXIMATION FORMULAS

Parameter	Formulas	Inputs
R2	$\frac{U_{R2}}{R2} = \frac{1.9966}{R2}$	R2
P2	$\frac{U_C}{C} = \frac{2(B\emptyset)^2}{(B\emptyset)^2 - Z\emptyset} \frac{U_{R2}}{R2}$	$B\emptyset$, $Z\emptyset$, $\frac{U_{R2}}{R2}$
	where $C = (B\emptyset)^2 - Z\emptyset$	$B\emptyset$, $Z\emptyset$
	$\frac{U_{P2}}{P2} = [(\frac{B\emptyset}{B\emptyset + SQR(C)} \frac{U_{R2}}{R2})^2 + (\frac{0.5C^{1/2}}{B\emptyset + SQR(C)} \frac{U_C}{C})^2]^{1/2}$	$B\emptyset$, $Z\emptyset$, C, $\frac{U_{R2}}{R2}$, $\frac{U_C}{C}$
Z1	$\frac{U_D}{D} = \frac{2(X1')^2}{D} \frac{U_{P2}}{P2}$	$X1'$, D, $\frac{U_{P2}}{P2}$
	where $D = (X1')^2 - (X\emptyset)^2 + 1$	$X1'$, $X\emptyset$
	$\frac{U_{X1}}{X1} = [(\frac{0.5D^{1/2}}{D^{1/2} - X1'} \frac{U_D}{D})^2 + (- \frac{X1'}{D^{1/2} - X1'} \frac{U_{P2}}{P2})^2]^{1/2}$	D, $X1'$, $\frac{U_D}{D}$, $\frac{U_{P2}}{P2}$
	$\frac{U_{X2}}{X2} = \frac{(X1)^2}{(X\emptyset)^2 + (X1)^2} \frac{U_{X1}}{X1}$	$X\emptyset$, X1, $\frac{U_{X1}}{X1}$

$$\frac{U_H}{H} = 2 \frac{U_{X2}}{X2} \qquad U_{X2},\ X2$$

$$\text{where } H = \frac{(X2)^2}{1 - (P2)^{G\emptyset}} \qquad X2,\ P2$$

$$\frac{U_{Z1}}{Z1} = \frac{H}{1-H} \frac{U_H}{H} \qquad H,\ \frac{U_H}{H}$$

Z3

$$\frac{U_{L1}}{L1} = 2 \frac{(X2)^2}{L1} \frac{U_{X2}}{X2} \qquad X2,\ L1,\ \frac{U_{X2}}{X2}$$

$$\frac{U_{Z3}}{Z3} = \frac{X}{1-X} \frac{U_{L1}}{L1} \qquad X,\ \frac{U_{L1}}{L1}$$

$$\text{where } X = \frac{L\emptyset}{L1} \qquad L\emptyset,\ L1$$

APPENDIX D

CALCULATION OF CONDENSATION EFFECTS IN THE STATOR NOZZLES

D.1 SUPERCOOLING IF CONDENSATION IS ABSENT

The present calculations follow the methods given in Cahpter 10 of Reference 13. The symbols used (in this section only) are as follows:

P_{t_o} = total pressure

T_{t_o} = total temperature

P = static pressure

T = static temperature

T_{DP} = dew point temperature

P_g = saturation pressure of the water vapor at the mixture temperature

P_w = partial pressure of the water vapor

P_a = partial pressure of the dry air

P = total pressure of the mixture = $P_a + P_w$

ϕ = relative humidity = $\frac{P_w}{P_g}$

γ = specific humidity = $0.622 \frac{P_w}{P_a}$

m = mach number

ΔT = $T - T_{DP}$

Subscripts

1 = compression intake

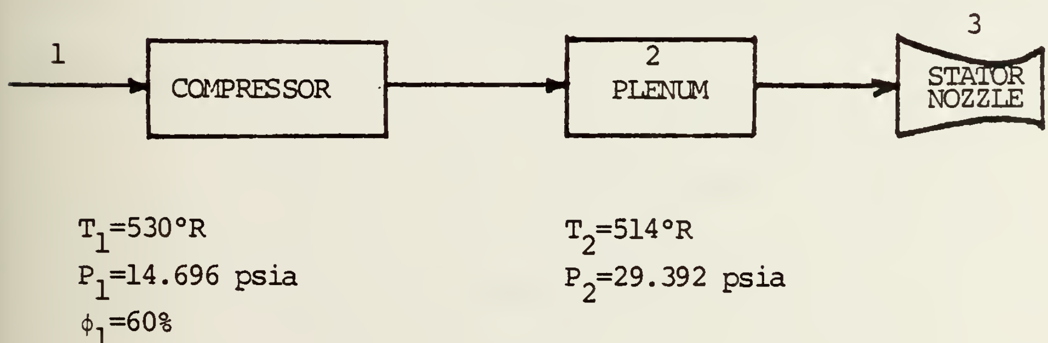
2 = turbine plenum

3 = stator nozzle

The purpose of the calculations which follow is to examine the static temperature variation in the flow through the stator nozzles and to assess the likelihood that condensation will occur. The calculations are carried out for the air-water vapor mixture entering the Allis-Chalmers compressor at typical Monterey weather conditions. The question is - does the normal air flow through the stator nozzle supercool sufficiently to produce condensation within the nozzle itself? The recorded weather data for Monterey for the days of the tests in this report showed a limited variation in relative humidity and temperature of ϕ = 60 - 70% and T = 60 - 70 °F respectively. Therefore, the following conditions were assumed:

$$\phi = 60\% \qquad\qquad T = 70\ ^\circ F$$

The process to be analyzed is shown schematically in the following sketch:



The calculations are for the worst case, say run 12 or 13, where the lowest supply temperature (T_{t_o} = 574 °R) would give rise to the greatest degree of supercooling.

The calculation is carried out as follows: First the pressure and temperature for a perfect gas isentropic expansion is calculated to an assumed Mach number. Then, <u>assuming the flow remains</u> saturated, but free of condensation the partial pressure of water vapor is calculated. From the known pressure and partial pressure the dew point temperature is obtained from tables. The degree of supersaturation is then the difference between the calculated gas temperature and the dew point temperature.

Since no water vapor is added in the compressor, the specific humidity of the air does not change from atmospheric inlet to stator nozzle conditions. At atmospheric inlet conditions,

$$\phi = 0.60 = \frac{P_w}{P_g}$$

where, at 70 °F, P_g = .3632 psia (saturation tables for water). Since

$$P = 1 \text{ atm} = 14.696 \text{ psia} = P_w + P_a$$

$$P_{a_1} = 14.696 - P_{w_1}$$

and

$$P_{w_1} = 0.60\, P_g = 0.60(.3632 \text{ psia})$$

$$P_{w_1} = .21792 \text{ psia.}$$

Therefore

$$\gamma_1 = 0.622 \frac{P_{w_1}}{P_{a_1}} = 0.622 \frac{P_{w_1}}{14.696 - P_{w_1}}$$

$$= 0.622 \left(\frac{.21792}{14.696 - .21792}\right)$$

$$= .00936 \frac{\text{lbm } H_2O}{\text{lbm air}} .$$

This fraction (γ) remains constant up to the point at which condensation occurs in the nozzle. Therefore, at station 2,

$$\phi_2 = \frac{\gamma P_{a_2}}{0.622 P_{g_2}}$$

where

$$P_{g_2} = 1.4436 \text{ at } T = 574 \text{ °R}$$

Since $\gamma_1 = \gamma_2$, then

$$0.622 \frac{P_{w_1}}{P_{a_1}} = 0.622 \frac{P_{w_2}}{P_{a_2}} ,$$

or

$$\frac{P_{w_1}}{P_{a_1}} = \frac{P_{w_2}}{P_{a_2}} = \frac{P_{w_2}}{P_2 - P_{w_2}}$$

Writing,

$$P_{w_2} = \frac{P_{w_1}}{P_{a_1}}(P_2 - P_{w_2})$$

$$P_{w_2}\left(1 + \frac{P_{w_1}}{P_{a_1}}\right) = \frac{P_2\ P_{w_1}}{P_{a_1}}$$

$$P_{w_2} = \frac{P_2\ P_{w_1}/P_{a_1}}{1 + \frac{P_{w_1}}{P_{a_1}}}$$

$$= \frac{29.392(.21792/(14.696 - .21792))}{1 + \frac{.21792}{14.616 - .21792}}$$

$$= .43584 \text{ psia}$$

Therefore the relative humidity at stagnation conditions is given by

$$\phi_2 = \frac{\gamma_2\ P_{a_2}}{0.622\ P_{g_2}} = \frac{.00936(29.392 - .43584)}{0.622(1.4436)}$$

$$= .3019$$

Now ϕ will increase in the flow through the nozzle from the plenum to the nozzle throat to the nozzle exit, since the static temperature in the flow progressively drops.

For the purpose of calculating supercooling in the higher mach number region of the expansion, from this point it will

be assumed that the flow is fully saturated, that is to say, $\phi = 1$. It will also be assumed that no condensation actually occurs, and therefore $\gamma = 0.00936$.

The dew points are calculated on the basis of the partial pressure, p_{w_1}. Therefore, at any station 3 in the nozzle, if $\phi = 1$,

$$\frac{P_{w_3}}{P_{g_3}} = 1.0$$

or

$$P_{w_3} = P_{g_3}$$

and

$$\frac{P_{w_1}}{P_{a_1}} = \frac{P_{w_2}}{P_{a_2}} = \frac{P_{w_3}}{P_{a_3}}$$

until condensation occurs. Therefore,

$$P_{w_3} = \frac{P_{w_2}}{P_{a_2}} P_{a_3} = \frac{P_{w_2}}{P_{a_2}} (P_3 - P_{w_3})$$

or

$$P_{w_3} = \frac{\frac{P_{w_2}}{P_{a_2}} P_3}{1 + \frac{P_{w_2}}{P_{a_2}}}$$

Since

$$\frac{P_{w_2}}{P_{a_2}} = \frac{.43584}{29.392 - .43584} = .015$$

$$P_{w_3} = \frac{.015\ P_3}{1 + .015} = .0148\ P_3$$

when P_3 is obtained from isentropic tables for the expansion, the dew point temperature is obtained using Table B1-b of Ref. 13.

The results of the calculations for 5 mach numbers (or nozzle statics) are listed in Table D-I.

Table D-I

CALCULATED SUPERCOOLING (ΔT) IF NO CONDENSATION OCCURS AT $T_{t_o} = 574$ °R ($P_{t_o} = 2$ atms, $\phi = 0.6$ at intake conditions $T = 530$ °R and $p = 1$ atms)

Station	Mach	P	T_{t_o}	T	T_{DP}	ΔT
1 (throat)	1.0	15.527	574	478	517	-39
2	1.2	12.121	574	446	510	-64
3	1.3	10.608	574	429	507	-78
4 (nozzle exit)	1.4	9.236	574	412	503	-91
5	1.5	8.006	574	396	499	-103

[Sample calculation: since $P_{w_3} = .0148\ P_3$, at station 2, $P_{w_3} = .0148(12.121) = .1797$ psia. From Table B1-b of Ref. 13, $T_{DP} = 510$ °R.]

The results of similar calculations for identical conditions except T_{t_o} = 670 °R, are given in Table D-II.

Table D-II

CALCULATED SUPERCOOLING OF (ΔT) IF NO CONDENSATION OCCURS AT T_{t_o} = 670 °R

(P_{t_o} = 2 atms, ϕ = 0.6 at intake conditions T = 530 °R and P = 1 atms)

Station	Mach	P	T_{t_o}	T	T_{DP}	ΔT
1 (throat)	1.0	15.527	670	558	517	+41
2	1.2	12.121	670	520	510	+10
3	1.3	10.608	670	501	507	- 6
4	1.4	9.236	670	481	503	-22
5	1.5	8.006	670	462	499	-37

Note that a negative delta T implies supercooling. The results for the lower temperature (T_{t_o} = 574 °R) indicate that the flow is supercooled from the throat to the exit plane, with ΔT = -103 °F at m = 1.5. Although the stator nozzle is designed for a Mach number of 1.4, expansion of the flow to the interstage pressure conditions will result in a slightly higher Mach number approaching 1.5.

D.2 EFFECT OF CONDENSATION ON PRESSURE

The effect of condensation on pressures which would occur in the nozzle expansion were calculated using the method given on P. 205 of Ref. 15. If the condensation process is treated

as one in which the heat of condensation, h_{fg}, is added in the expansion process and acts to increase the stagnation temperature, then the effect on the static pressure is given by

$$\frac{dP}{P} = - \frac{Km^2(1 + \frac{K-1}{2} M^2)}{(1 - M^2)} f(\frac{h_{fg}}{C_p T_{t_o}})$$

where K = ratio of specific heats and f = mass fraction which condenses. Using K = 1.4,

$$h_{fg} = 1000 \text{ Btu/lbm}, \quad C_p = .45 \text{ Btu/lbm-°R}$$

and

$$T_{t_o} = 574 \text{ °R},$$

and letting M = 1.2,

$$\frac{dP}{P} = - \frac{(1.4)(1.2)^2(1 + 0.2(1.2)^2)}{(1 - 1.2^2)} f(\frac{1000}{.446(574)})$$

$$= 23.05 \text{ f.}$$

Consequently for a 1% change in the pressure ratio to occur ($\frac{dP}{P} = 0.01$),

$$f = 0.01/23.05 = .0004338 \frac{\text{lbm } H_2O}{\text{lbm air}}.$$

If this is the fraction of the total gas flow which is required to condense, then the fraction of the water present in the flow required to condense is given by

$$\frac{f}{\gamma} = \frac{.0004338}{.00936} = .046336.$$

Hence, 4.6% of the water in the flow would have to condense at M = 1.2 station to produce a 1% change in the pressure ratio.

APPENDIX E

RIG PROCEDURES

1. Prior to each run, observe and record the calibration of:

   a. stator axial force capsule

   b. stator torque capsule

   c. rotor torque capsule

   d. closure plate axial force capsule

   e. ΔP_{noz}

2. Ensure aftercooler is drained so that a consistent high T_{t_o} will be obtained for the run.

3. Observe and check calibration of the stator axial force capsule and ΔP_{noz} before and after each point to ensure consistency.

4. Avoid points in the 17000-18500 RPM range to avoid data scatter in this region.

5. Include smaller increments of KIS, i.e., smaller RPM changes between points to more clearly define graphed parameters. A spacing of 500 RPM between points would be suitable.

6. Allow a minimum of 3-5 minutes after recording data and setting a new operating point, for conditions to stabilize.

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